Material Technology and Science in Manuscripts of Persian Mystical Literature*

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Abstract

Mysticism has always been part and parcel of Persian art and literature. So far, however, the scientific aspects of it have been overlooked by art historians and scholars. The aim of this study is to investigate how researchers can uncover the reasons for the choice of substances used to produce such works from the huge amount of information found in historical sources and to present some case studies to show how science should look at this kind of literature. The research presented here focuses on introducing a theoretical and methodological approach and is illustrated by three examples that reveal the reasons behind the use of certain ingredients in the Persian art of book-making, namely saffron, henna and cucumber-seed mucilage to make verdigris pigment and paper dye and influence the sizing process. Examples of poetic treatises from the thirteenth to the nineteenth century are presented that were written by master calligraphers. The scientific laboratory investigation that was carried out on the works will be reported as evidence revealing the premodern scientific knowledge behind their mystic recipes.

Introduction

Traditional Persian arts and crafts are not only considered to be simple works of handicraft but are committed to an aesthetic standard that encompasses pure manual perfection. When the artist strives for a state of perfection his or her striving has a religious meaning as well. Hence perfection is a mystical quality that in its absolute sense refers to the divine sphere.¹

The following poem by Solṭān ʿAli Mašhadi (841–926 Hijra/1437/1438–1519/1520 CE) found in a chapter about calligraphers included in his treatise Ṣerāt al-Ṣoṭur is a fine example that links reaching a state of perfection in calligraphy to self-purification:

**Dr Bāb Khosnūsesan**

ای که خواهی که خوشنویس شوی
حقل را مونس وانیس شوی
عامی پر زنام خود سازی
ویل زعید شباع باید کردن
ترک آرام و خواب باید کردن
سربه کاغذ چو خامه فرسودن
زرد طلب روز و شب نیاسودن
زاروزهای خویش بگشتن
نفس بکش رازدگردن
نسب با نفس بژد وردنه
باز گمشن به سوی اکثر چیست
به چک کس را بپایان نیازار
کر دلارا حک بود بیزار
از درغو وزغیت ورتخان
پر طهارت میثاب یک ساعت
صفت ناخوش اختیار مکن
هیچکر یک که تا کمک و مکر را شعار نکن
زا چه کس از مکر و مکر و تلیس
دان انسک که آشنا نیست
خط لوشنن شعار نپاکانست

About Calligraphers

If you wish to become a calligrapher and to love and be loved by people,

If you want to be a resident of the land of script and make your name known all over the world,

You must renounce sleep and rest, you should start doing this when you are young.

You should bend your head down at all times like the nib of the reed pen,

You must not let this wish fade at all day or night,

You have to renounce all your desire, and avoid greed and envy,

¹ I am grateful to Professor Amir Hossein Zekrgoo for his kind assistance in translating some of the Persian poems quoted in this paper into English. I would also like to thank the anonymous reviewers and the editorial team of the Centre for the Study of Manuscript Cultures

You have to constantly fight with your ego until you slaughter it so that you learn what the lesser jehād (jehād-e aṣḡar) is and what it means to set out towards God (akbar).

Don’t do anything to others that you wouldn’t do to yourself.

Never hurt the heart, because God dislikes heart-hurters avoid lying, back-biting and making false accusations at all times.

Always be in a state of contentment and thankfulness [to thy Lord] and observe [ritual] purity and cleanliness constantly.

Avoid tricks and fraud and do not let bad attitudes affect you.

Whoever is able to cleanse himself from machinations, deception and pretence will become a fine writer.

Those who are aware of manners of the heart know that fine handwriting emanates from a pure heart,

Fine handwriting comes from those who are pure, sitting idle is what the ignorant do.

To achieve this task, in bygone days, the Iranian artist always took care not only to purify him- or herself through this journey, but also to try and create a piece of art in a perfect manner, symbolising the balance, harmony and organic relations that rule in the universe by using only the best materials and the most advanced techniques in his work. He or she also took care to ensure the artwork created was not faulty in any way, but was capable of lasting a long time and that the ageing process of the artefact could be minimised. For this very reason, the artists had to equip themselves with the scientific knowledge in order to understand the nature of the materials used and to apply techniques that could reduce any damage due to physical, chemical or biological deterioration over time.

Objectives of the research

This study was conducted on a number of examples of historical poetic treatises written by Iranian master calligraphers in order to reveal the empirical knowledge underlying their work. In these selected exemplars of Persian literature, they discussed the art of book-making and miniature-painting, revealing their expertise in the art of calligraphy, ink-making and the preparation of sizing materials to apply on paper to prepare a suitable basis for calligraphy. Besides finding recipes on the art of calligraphy, one can discover a great amount of knowledge on the art of making dyes and pigments used by artists to create Persian miniatures and illuminate manuscripts. In many cases, the recipes contain elements that the masters advised readers to add or avoid. On account of the research I conducted, I found that this advice was based on reasons that can be identified as underlying stipulations to prevent the works of art from getting damaged or deteriorating. One can discover the reason for the stability of Persian manuscripts and miniature paintings by studying Persian literature. The scientific laboratory investigations that were carried out for the study are presented here as supporting evidence for my claims.

Methodology of the research

The methodology used in the present study is based on historical and scientific analyses. In the first phase, a historical analysis based on 24 treatises belonging to the Timurid (eighth–ninth century Hijra/fourteenth–fifteenth century CE), Safawid (tenth–twelfth century Hijra/sixteenth–eighteenth century CE) and Qajar periods (1193–1344 Hijra/1779–1925 CE) was carried out to identify ingredients that were advised by painters and calligraphers during these eras. In this research, all the identified treatises were examined thoroughly, but only a few examples of them can be presented here (see appendix A).

In the second phase, a number of case studies were undertaken by the author based on laboratory work on original historical samples of illuminated Persian manuscripts and miniature-painting; these complement the objectives of this research. In this scientific analysis, the use of certain ingredients recommended or emphasised by the master calligraphers was studied to discover the reasons for them picking the elements described in the recipes. All the recommended elements were found to be science-based and were used as a preventive measure in historical illuminated Persian manuscripts, miniature-paintings, paintboxes, and palettes.

Scientific analyses have tried to identify the elements in the Persian historical treatises that were particularly recommended – the masters made a point of stressing certain elements to add or avoid.3 With this in mind, saffron was studied as a

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3 These scientific analyses were carried out in several phases by the author and co-authors in order to identify the use of certain ingredients recommended or emphasised by the master calligraphers and collected from historical analysis data. The results of these analyses have been reported in detail in various publications (Barkeshli 1999, 2002, 2003, 2008a, 2008b, 2009, 2011, 2014).

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corrosion inhibitor, henna as a fungicide and cucumber-seed mucilage as a suitable sizing material. To this end, original samples taken from fifteen Timurid- to Qajar-period miniature Persian paintings, illuminated manuscripts and paintboxes from museums and private collections were gathered for analysis. The samples were analysed in a laboratory to identify pigments using Spot Test, X-ray Diffraction (XRD), Fourier Transform Infrared Spectroscopy (FTIR) and Polarised Light Microscopy (PLM). In many cases, a number of ingredients were prepared based on the historical recipes found in the Persian literature and they were used as controls for FTIR analysis of their spectra, in order to identify sizing materials and saffron in green verdigris pigment as an inhibitor. To identify the property of some of the elements, analytical procedures were carried out using fungus cultures in the case of henna and standard procedures were followed to identify the buffering property of an element in the case of saffron.

Case study I: the mysterious presence of saffron in Persian green

The first case study was intended to unravel the mystery of why saffron dye was used to prevent the corrosive effect of green verdigris (zangār)⁴. Before the rise of the chemical industry at the beginning of the twentieth century, verdigris pigment was commonly used as a green paint in Persian miniature paintings and for colouring the borders (ḥāšiyeh) of illuminated manuscripts. Basic verdigris is the only green pigment which appears in the preparation of zangār in mediaeval Persian texts, i.e. writings from the Timurid to the Qajar periods. Three different techniques are described in the historical literature:

Persian recipes

The first technique for making zangār is described in quite a similar manner by at least four authors, viz. by Solţān Aḥmad Majnun Rafiqi Heravi, Mir ‘Ali Heravi, Hossein Aqili Rostam and Alkašfi. In his treatise Savād al-kāṭt, Solţān Aḥmad Majnun Rafiqi Heravi described the technique as follows:

Various writers described a second technique for making zangār: Solţān Aḥmad Majnun Rafiqi Heravi, Seyrafi, Sadeq Bek Afsar, Ali Hosseini, Alkašfi and two anonymous artists in Resāleh dar Bayān-e Kāḡaḏ va Ḥall-e Alvān and Resāleh dar Bayān-e Sāḵtan-e Morakkab va Kāḡaḏe Alvān. In his book Morakkab Sāzi va Jeld Sāzi Ali Hosseini explained the process as follows:

The other type is to mix copper pieces and strong old grape vinegar in equal proportions. Keep this in a vessel and hang it in a well for forty days. When you take it out, the copper will have changed to verdigris of extremely good quality.

Ṣādeq Bek Afsar describes another method in greater detail in Qānun al-Ṣovar:

Dig a well two gaz⁶ deep in a moist place, [hang] thin blades made of clean copper into it. Pour down as much unfiltered vinegar as the soil can absorb, cover [the well]. Leave it there for almost a month – don’t worry if it is a couple of days more or less [than that]. After a month, you will see that the entire [copper] has turned into an attractive verdigris.
Several writers explained a similar alternative procedure to that mentioned above, except that the use of yoghurt made from sheep’s milk was recommended instead of vinegar: Mir ‘Ali Heravi did this in Medād al-Ḵoṭūt, ‘Ali Hosseini in Morakkab Sāzi va Jeld Sāzi, Alkašfi in Bayān al-Ṣenāʿat and an anonymous artist in Resāleh dar Bayān-e Kāḡaḏ Morakkab va Ḥall-e Alvān.

The introduction of saffron as an inhibitor

It seems artists soon recognised the instability and destructive nature of some pigments. Cennini (1954), for example, mentioned that verdigris is beautiful for painting eyes, but does not last. Theophilus warned against using ‘green salt’ for book illumination as ‘it is not good for books’. \(^8\) This phenomenon was not unknown to Iranian artists. For example, in Resāleh dar Bayān-e Kāḡaḏ Morakkab va Ḥall-e Alvān cautious use of verdigris was recommended after describing the techniques of making it: ‘... zangār is not stable and will char the paper’.

What is noteworthy, however, is that some of the old Persian recipes describe the addition of saffron to verdigris as one of the measures to counter its destructive effect. Mir ‘Ali Heravi mentioned this in Medād al-Ḵoṭūt, ‘Ali Hosseini in Morakkab Sāzi va Jeld Sāzi and Alkašfi in Bayān al-Ṣenāʿat mentioned the destructive effect of zangār made from yoghurt and recommended saffron to be mixed with zangār to prevent its charring effect on paper in the last part of their recipes. According to Mir ‘Ali Heravi in Medād al-Ḵoṭūt:

\[^7\] Anzarut: sarcocolla, flesh-glue.


Besides being used as a preventive measure against the destructive effects of zangār, saffron was also recommended for obtaining different shades of green. For example, Ali Seyrāfī poetically states in Golzār-e Ṣafā:

\[
\text{زعفران داخل زنگار نما}
\]

The smiling green pistachio that resembles your beautiful lips whispers tenderly.\(^9\)

Mix saffron with zangār and move your pen with it gracefully.

As one can see from mediaeval Persian texts, mixing saffron with verdigris was a common practice among Iranian artists. It was used either as a preventive measure recommended by their masters or for obtaining a popular green pistachio colour, as recommended in old recipes.

**Scientific analysis**

An examination was carried out in two stages to investigate whether saffron has any chemical properties that prevent the destructive action of verdigris and whether traces of saffron can be found in original samples of mediaeval writing which have prevented the charring effect of verdigris.

The first step was conducted to ascertain the presence of saffron as an inhibitor in verdigris pigment. Original samples were selected from the Iran Bastan Museum as well as from private collections, and their green pigments were analysed in a laboratory.\(^10\)

A second examination was carried out to investigate the possible buffering properties of saffron, since the change of

\[^9\] Literal translation: ‘If like calligraphy your lip, my beloved, wants pistachio, listen to it.’ The poet uses a double understanding of mayl kardan, ‘eat’ and ‘want’. The lip of the beloved eats pistachio whereas calligraphy needs it. The double understanding is further stressed in the end of the first verse: bi-shinaw az ān, listen to it, and ‘it’ can be the lip (a lip can eat pistachio and want it) and calligraphy as well.

pH from a low level to a high one plays an important role in the destructive mechanisms of copper-based pigments.\(^{11}\)

**Materials and techniques**

In the first phase, the presence of saffron in verdigris pigment was investigated, as advised by masters in order to prevent the destructive effect of verdigris, and the green pigments of twelve miniature Persian and Indian paintings, illuminated manuscripts and paintboxes from the Safawid to Qajar periods were analysed along with the paint palettes of two traditional Persian artists of the time. To identify the chemical composition of green pigments used in the sample collection, different techniques were employed, including microscopic analysis, micro-chemical analysis, FTIR and XRD methods.

The optical appearance of the pigment mounted in Canada balsam (\(N = 1.53\)) on a microscopic slide was observed in reflected and then in transmitted plain polarised light. The identification of some pigments was confirmed by determining the presence of copper in the case of copper green pigment and iron in the case of green terre-verte by a positive test for copper or iron with potassium ferrocyanide using chemical microscopy. The different copper-based pigments such as verdigris, malachite, atachamite and langite were identified using FTIR by confirming the presence of acetate, carbonate, chloride and sulphate. Sample preparation was done by mixing potassium bromide (KBr) with the unprepared sample (100:1). The materials present in the samples were identified by comparing the infrared spectrum with the reference spectra via recognition of specific bands. X-ray powder diffraction supplied evidence of specific minerals when a large enough sample was available. Green pigments collected from original samples were present in extremely small amounts except in one case, which belonged to a paint palette collected from traditional artists.\(^{12}\)

A complete record of the pigments found in samples from private collections and selected paintings from Iran Bastan Museum is shown in table 2 (appendix B) along with an indication of the corresponding identification methods. Of the twenty green pigments analysed, nine were identified as being green, copper-based pigments and the rest were found to be mixtures of yellow and blue, whereas no terre-verte was identified. Of the nine green, copper-based pigments examined, five were identified as green copper acetate, whereas two were found to be pure verdigris and three were identified as verdigris mixed with saffron.

Figure 1 shows the spectra of pure verdigris used in illuminated Persian manuscripts (appendix B, table 2, checklist no. 13).

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11 Barkeshli and Ataie 2002.

12 Paintboxes collected from A. Tavoosi belonging to the sixteenth century and from M. Bekhradi belonging to the nineteenth century from Isfahan, Iran.
Fig. 2a: A seventeenth-century illuminated Persian manuscript with green verdigris in its pure form, Atiqi Collection, Tehran, Iran (appendix B, table 2, checklist no. 13).

checklist no. 13, fig. 2a and fig. 2b); bands 1400, 1500 and 1600 indicate the presence of acetate. Confirmation was provided by determining the presence of copper by microchemical analysis and by its microscopical appearance. Fig. 3 shows the presence of saffron mixed with verdigris found in a sixteenth century miniature Persian painting (appendix B, table 2, checklist no. 18; fig. 4); bands 1400, 1500 and 1600 show the presence of acetate. In this sample, it can also be clearly seen that the spectra exactly matched the fingerprints of saffron spectra which were used as a reference. The noticeable distinction when comparing the bands on 3439 is related to the possible effect of the local formation of alkali hydroxide on the trend of the destruction of the verdigris in pure form and verdigris mixed with saffron.

In the second stage for comparing the pH resistance of saffron with buffers and water, the pH profiles were

Graph 1: pH variation of different solutions due to incremental addition of acetic acid 0.01 M.
determined over a range of pH 0–14. Five solutions were prepared: 20 ml of distilled water, two different saffron solutions of different concentrations; 20 ml of a 0.4% saffron solution (0.4 grams of saffron in 100 ml of distilled water) and 20 ml of a 1% saffron solution (1 gram of saffron in 100 ml of distilled water), 20 ml sodium acetate-acetic acid (acidic) buffer 0.01 M and 20 ml ammonium chloride-ammonium (basic) buffer 0.01 M. Distilled water and saffron solutions were divided into two portions. 0.01 M of acid (CH₃COOH) was gradually added to one portion and a 0.01 M base (NaOH) to the other. As for the buffers, acetic acid was added to the basic buffer and sodium hydroxide to the acidic buffer. Then the pH of all the solutions was measured and compared. The pH variations of different solutions due to the incremental addition of acetic acid are summarised in graph 1: One can see that the pH of 1% solution of saffron is maintained at 5.5 when gradually adding up to 2 ml of acetic acid to the solution, while the acetic acid solution alone indicated a gradual decrease of pH; 2 ml resulted in pH 4.3. Experimentation with a 0.4% saffron solution also showed a similar though less significant trend. In this case, the pH starting from 5.6 was lowered to 5 on the addition of 2 ml of acetic acid, which was almost equivalent to the solution without acetic acid. It is evident that the pH variations in the saffron solutions are lower than the variations in water and that the buffering property of saffron is strengthened by increasing the concentration. The graph shows the behaviour of saffron solutions in comparison with a basic buffer, i.e. ammonium chloride-ammonium acidic solution.

Fig. 3: The spectra of green verdigris mixed with saffron in a Persian miniature painting (appendix B, table 2, checklist no. 18). The red line is the reference and the blue line is the green verdigris sample from the manuscript.

Fig. 4: A sixteenth-century Persian miniature painting with its green verdigris mixed with saffron, Atiq Collection, Tehran, Iran (appendix B, table 2, checklist no. 18).
Graph 2 shows the buffering behaviour of the saffron solutions in a basic medium. The corresponding behaviour of distilled water and sodium acetate-acetic acid, which is an acidic buffer, is also shown as a reference. It is clear that the saffron solution is a stronger buffer than the acidic buffer under study and its buffering effect increases with an increase in the concentration. As the concentration of NaOH was gradually increased from 0.2 ml to 2 ml, the pH only increased to 6.3, while the pH of the NaOH solution with a 2 ml concentration was 10.4. Even the 0.4% solution of saffron had a sufficiently strong buffering characteristic. In this case, the addition of 2 ml of NaOH resulted in a pH of 6.8, which is higher than that obtained by a 1% solution of saffron and 2 ml of NaOH.

Results and summary

Right from the very first phase of the investigation, the study lent support to the idea of saffron having a preventive quality: the research showed verdigris which was mixed with saffron did not char the paper, whereas the verdigris which was used in pure form charred the paper extensively. Figures 2a and 2b and figure 4 show the condition of green pigment in miniature Persian paintings and illuminated Persian manuscripts when verdigris was used in its pure form and mixed with saffron. During the investigation, saffron mixed with green verdigris was found in a sixteenth century paintbox from the Safawid period (see fig. 5). This proves the use of saffron mixed with verdigris in Persian paint palettes to obtain pistachio green, as recommended by the masters.

By comparing graphs 1 and 2 from the second stage, it can be observed that the pH variations of the 1% saffron solution, ranging from 5.5 to 8.5, are quite minimal compared with the variation of pH in the acidic buffer, which ranges from 5 to 11, and that of the basic buffer ranging from 4.8 to 9.2 in an identical condition. The results of a previous\textsuperscript{13} investigation show that saffron can resist a wide range of pH variations and that the existence of unsaturated dicarboxylic acid and its esters (crocin, carotenoid esters and crocetin) and nitrogen compounds in the chemical composition of saffron could be responsible for its high resistance. It therefore proves that the saffron solution,
when added to the verdigris pigments, acts as a powerful buffering agent which prevents the charring of paper by maintaining a constant pH. This prevents the destructive mechanism of verdigris from unfolding by increasing the pH and the local formation of alkaline hydroxide, which is active in the final stage of the degradation process due to a Fehling reaction.

Case study II: the mystery of the henna dye recommended in Persian literature

The art of calligraphy and illumination which emerged during the Islamic period has great relevance for the history of the arts. Paper was first produced in Khorasan in the eastern part of the Islamic world by Chinese captives in the second century Hijra (around 750). It spread to other Islamic territories and soon became a significant commodity in the Islamic world. Persia actually developed into one of the most important centres for papermaking and was a bridge that connected East and West in this art, which became so popular in Iran that there were some cities where the entire population engaged in it. During the period of Yāqut, for instance (sixth and seventh centuries Hijra), there was a city called ‘Kāḡaz konān’ (the ‘city of paper producers’), located between Marāḡeh and Zanjān, which was famous for producing quality paper; almost everyone in that city engaged in paper production. The growing demand for paper on the part of scribes and men of letters prompted papermakers in the Islamic Middle Ages and subsequently those in the Timurid and the Safavid eras to focus upon the aesthetic aspects of paper production and to produce a wide-ranging variety of paper.

A number of treatises relating to methods used in paper-dyeing during the periods under study have survived and are accessible to us today. Historical evidence from the Timurid and Safavid eras, including the Qajar period, has revealed that the paper used for producing books in these years was generally dyed. Experts on the field of papermaking recommended dyeing the paper in two respects: one was the aesthetic aspect and the other the effect of the paper’s colour on the reader. According to them, white paper had a harmful visual effect on the reader, while dyed paper reduced the strain on the reader’s eyes. In his famous treatise entitled Golzār-e Ṣafā, Seyrafi, a renowned expert from the Safavid period, says the following:

Paper once dyed is better, for white surely harms the eyesight one hundred times.

It is not favourable to hurt the eyes, it is wise to refrain from penning on uncoloured paper.

First, dye the paper to beauty, so that your hand and eyes remain fine.

Since I expect you to scale great heights in this art, I have helped you with this little part.

In some old treatises, references have also been made to the harmful effects of certain kinds of dyed paper on the eyesight with regard to the ink used for calligraphy and the dyes employed for colouring paper – Mohammad Boḵāri and Solṭān ʿAli Mašhadi discussed this matter in almost the same way in their respective works, Favāyed al-ḵoṭuṭ and Ṣerāt al-Ṣoṭur, for example. The latter mentions the following:

14 Māyel Heravi 1993, 16.
15 Māyel Heravi 1993, 17.
16 Māyel Heravi 1993, 17.
Eyes get dazzled when they see red, yellow and white paper just as they do while looking at the sun.

For the purpose of calligraphy, temperate colours should be used as they relax the eyes. The coloured lines are good on dark paper.

Write on red paper with white colour so that your handwriting (calligraphy) stays nice and elegant. On blue paper, writing with white is pleasant.

However, in his treatise, *Fāvāyed al-ḵoṭuṭ*, Mohammad Boḵāri points out the following about other colours:

لای بعضی رنگهای دیگر هست نوشتن خطا است وبه خط سیاهی در او نوشتن سبب خورشید چشم می شود ورنگ سرخ وسبز وسوسنی وماویِ سیر وسیم تیره می سازد.

There are some more colours with which it would be a mistake to write, and writing on them with black ink will dazzle (blind) the eye. Red, green, dark blue (violet), full blue, and white make (the eye) dark.

Red, green and white dazzle the eye (make it blind) like looking into the sun. Full blue, dark blue and violet also make the eye dark and moist.

The most recommended dye for colouring paper: henna

One of the methods that have always attracted experts’ attention is paper-dyeing with natural extracts of henna. This has been used in various ways throughout history.

Among the different coloured papers, henna is specifically recommended for making natural colour (*ḵodrang*) in historical documents either in its pure state or when mixed with saffron. For example, Bābā Shāh-e Isfahāni poetically says in his treatise *Ādāb al-Maṣq* that:

هیچ رنگی به از حنایی نیست       حاجت آنکه آزمایی نیست

No colour is better than the colour of henna, I will tell you what the colour is made of.

Saffron and henna and a few drops of ink, do not allow any more [than that].

Both calligraphy and gold will go with it nicely, it is the ornament of fine, high-quality writing.

As mentioned earlier, henna dye was recommended by different masters based on their own experience. Perhaps that is why this colour was used so much in Persian paper manuscripts. Most historical treatises put more emphasis on the ratio of henna and water for obtaining the dye. This was also explained in various historical sources that were studied, including *Resāleh dar Bayān-e Kāḡaḏ Morakkab va Ḥall-e Alvān*, *Golzār- e Ṣafā*, *Resāleh dar Bayān-e Tariqe-ye Sāḵtan-e Morakkab va Kāḡaḏ-e Alvān* and *Resāleh dar Bayān-e Rang Kardan-e Kāḡaḏ*. In all these sources, the methods used for making henna are almost the same. In *Resāleh dar Bayān-e Kāḡaḏ Morakkab va Hall-e Alvān,*
Oh friend, if you want to dye paper in *ködrang*, harmonise yourself with this colour.

First of all, heat some water and then add the henna leaves to it in the right proportion.

Paper receives its joy from your dye. Afterwards, let it dry in the shade.

Acquire large quantities of henna leaves and clean them by freeing them of dust.

Be aware and conscious about the weight of the henna dye: it should be one portion of henna leaves and ten portions of water.

Leave [the mixture] a day and a night, then filter the liquid and use it as a dye.

It should be mentioned here that a lower concentration of one

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*fir* of henna and half a *mann* of water was only recommended in one treatise, *Resāleh-ye Šahāfi*, whereas in the treatise *Resāleh dar Bayān-e Rang Kārdān-e Kāḡad*, the ratio was not indicated at all; instead, the writer advised the reader to obtain the desired colour by trial and error.

Since all our sources strongly advised dyeing paper with henna, I studied the anti-fungal properties of henna and conducted a scientific examination in the second phase of the study.

### Scientific analysis

In this analysis, the effects of henna extract were specifically examined to explore the reason for it being used for paper-colouring, as repeatedly advised by masters in Persian historical treatises, who recommended employing a ratio of one part henna to ten of water. The analysis was carried out in two stages.

#### Materials and techniques

In the first stage, the chemical composition of henna was reviewed and its colouring matter was investigated. It was found that the leaves of henna contain 7% tannin, 6% fat, 1.2% essences and 2–3% lawsone (2-hydroxy-1,4-naphthaquinone) responsible for the anti-microbial properties of henna.

It was also found that henna has fungicidal properties, as previously reported by Soker.

In the first stage, an examination was also carried out to investigate the relation of *aspergillus flavus* fungus growth on paper with the concentration of henna dye without taking into account the ratio that was advised by the masters. Three different samples of undyed and unsized historical handmade paper from the sixteenth to the nineteenth centuries – seemingly of different grammage and different fibres – were selected from the conservation laboratory of the Iranian Parliament’s library in Tehran where papers were divided into three groups. In each of these, the papers were divided into four pieces of 2.5 x 2 cm in size for the sample experiments.

To dye the samples of paper without any consideration of the ratio advised in the historical recipes, 1, 2 and 3 grams of powdered henna leaves (prepared from Yazd in central Iran) were soaked in 60 ml of distilled water (1.8–3.3 and 5% respectively) in three separate containers and kept under artificial light for four hours to see how the henna dye

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17 *Ködrang* preserved the natural colour of the material, leaving it unchanged; at the same time it was a yellowish colour.

18 *Sir* is a traditional Iranian measure equivalent to 75 grams.

19 Malekzadeh 1968; Malekzadeh and Shabestari 1989.

Procedure. All the samples were diluted in double-distilled water and then sterilised in an autoclave for 15 minutes at 121°C. The laboratory work was conducted directly on the henna solution in concentrations of 2.5%, 5%, 7.5%, 10%, 12.5%, 15% and 17.5%. These solutions were incubated for two hours at 75°C. To get the complete extract, the solutions were kept at room temperature for 24 hours and then filtered. The extracted solution was used to culture the fungus. One gram of Sabouraud dextrose agar brass was mixed into 15 ml of henna solution extracts where the samples were all sterilised. In this phase, the research was only done on the henna solution to see the result. In the next phase, which is still to come, the result on henna paper will be examined as well. Aspergillus flavus fungi were inoculated into all the henna samples: 2.5% (plate a), 5% (plate b), 7.5% (plate c), 10% (plate d), 12.5% (plate e), 15% (plate f) and 17.5% (plate g), including untreated samples (plates 1 to 4), and the samples were studied every twelve hours (see fig. 7).

Results and summary

In the first stage, the results showed that the samples which were dyed with henna had a greater tendency to inhibit the growth of Aspergillus flavus fungus than the undyed paper samples. The samples dyed with henna showed that the growth of the fungus depended on the concentration of henna and the length of application: the growth of the fungus decreased if the concentration of henna was higher and the application took longer. As for the type of paper used, this did not lead to any significant difference in behaviour. It should be noted that even when the highest concentration of henna was employed and the dye was applied for a long time, the growth of the fungus decreased, but it was still noticeable – perhaps due to the lower concentration of henna dye used in the experiments (1.8–3.3 and 5%) rather than the advised ratio of 10% in the masters’ recipes.

In the second phase, our experiment showed that henna dye can only act as a fungicide that combats the Aspergillus flavus fungus if it is used in a concentration of more than 10%. Fungal growth in a henna extract with a higher concentration than 10% was reduced by 60% and was further reduced by 80% in a 17.5% henna concentration (see fig. 8). This means that the recipes suggested by Iranian masters in the fifteenth and sixteenth centuries may have been based on their knowledge of empirical chemistry and that henna dye was used to prevent fungus growth on paper, more specifically to counter Aspergillus flavus. To be able to
confirm this statement, though, further research needs to be carried out on other species of fungus and different types of paper, of course.

**Case study III: techniques and materials used in sizing paper**

‘Sizing’ (āizi) paper is a process of preparing the surface of paper to make it suitable for writing, illuminating or painting on. After a sheet of paper has been formed and dried, the cellulose fibre it contains can continue to absorb water unless it has been ‘sized’, i.e. impregnated with a substance like starch, glue or wax to prevent such penetration. There are different techniques available for sizing paper, depending on requirements, such as soaking or applying one or a number of layers of sizing material on the paper surface with the help of a soft brush.

Specimens from China (third century CE) indicate that contemporary papermakers used a range of sizing techniques, from coating the surface of the paper with gypsum to treating it with gum, glue or starch to prevent ink from spreading in an undesirable way. According to Hunter, one of the earliest methods of sizing paper was covering the surface of the sheets with a thin coating of gypsum. The next improvement was to render the body of the paper and the surface of it impermeable to ink by the use of lichen, starch or rice flour.

In Iran, according to Canby, once the paper was dried, it was sized by soaking it in albumen or a starchy solution to fill in and even out the surface for painting. Before the Islamic era, in the Sassanid period (fifth–sixth century CE), the Iranians used sizing materials over the cloth to prepare the surface for writing and painting. After learning the process of papermaking from the Chinese, Iranians started the tradition of sizing paper to prepare a suitable surface on it for writing and painting. The chief contribution of Iranian papermakers working under Arab rule was the perfection of rag paper thanks to improved techniques for beating the

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23 Hunter 1957, 194.
24 Canby 1993, 14.
fibres and by preparing the surface for writing by sizing it with starch.  

Certain scientific investigations have also revealed valuable information on materials used in the sizing process. According to Wulff and based on chemical investigation, the Iranian papermakers at Samarqand made an important contribution to papermaking by introducing a new method in sizing paper to make it more suitable for writing on with ink and a reed pen. Wheat starch and later gum tragacanth were used as sizing substances.

Persian recipes

A number of different sizing materials were prescribed in Persian historical treatises. Our historical analysis was preliminarily based on eleven treatises from the thirteenth to the eighteenth centuries. Most of the authors of these historical treatises are known to us today, while others are anonymous. These sizing materials are described in historical treatises from the late Seljuk and early Ilkanid (seventh-eighth century Hijra/twelfth-thirteenth century CE), Timurid (eighth-ninth century Hijra/fourteenth-fifteenth century CE), Safavid (tenth-twelfth century Hijra/sixteenth-eighteenth century CE) and Qajar periods (1193-1344 Hijra/1779-1925 CE), as we shall see below.

In his treatises Adāb al-Mašq, Rasīm al-Ḵaṭṭ and Savād al-Ḵaṭṭ, Solṭān Ahmad Majnun Ṣafarī advises the use of soft, smooth and even paper to write or draw on. To make fragile paper strong enough, reduce the fluffiness of paper fibres and make the surface of the paper smooth enough to write on, Mohammad Boḵārī also recommends applying sizing materials in his work Favāyed al-Ḵoṭuṭ.

In Ḥaliyyat al-Ketāb, the term dāru is used for sizing, whereas Teflīsi calls the sizing gune dādan. Simī uses this last term just once when referring to a marshmallow starch. Three elements are involved in the sizing process: a base (takte) to spread paper on it during the sizing process, sizing substance (āhār) to apply on the paper in order to smooth the paper fibres, and burnishing tools (mohre) to make the sizing adhere to the paper fibres and make the paper even and ready for writing on.

Historically, besides the type of fibre it contained and the place of its production, paper was known by different names, partly depending on the sizing of the sheets. In his book, Yves Porter quoted from Resāle-ye ḵošnevisi, where kaṭṭai’i paper is described thus: ‘to size kaṭṭai’i paper, whether it is meant for exercise or for calligraphy, if the starch is thick, we repeat the process two or three times.

In Ḥaliyyat al-Ketāb and Majmu’at al-Sanā’i we can find recipes for sizing paper in such a way that the paper becomes similar to Baghdadi paper, a kind of well-known paper made in Baghdad and mentioned in historical treatises. Also, different sizes were used as an appropriate base or support for calligraphy or painting according to requirements. Different types of paper, such as a single sheet of paper, two-layered paper (kāḡaḏ-e do puste) or three-layered paper (kāḡaḏ-e se puste), paper board (muqawwā) and albums (muraqqā) were made using sizing materials. Ghomāl Dehlavi describes the process of album preparation by instructing the pages of manuscripts to be sized and burnished on both sides: ‘Size the paper on the front but not on the back, with great care, like a fresh colourful flower. Then polish the paper on the other side until it shines brighter than a mirror for writing.’

From our study, the materials can generally be categorised as proteinaceous materials, which include animal glue, starch from rice or wheat, vegetable gum, or mucilage from plants and seeds, fruit or sugar. A number of burnishing materials were also employed, such as agate stone (aqiq), jayn (vašm), ivory (āj), glass (zejāj), crystal (bolur) and shell (jis). Teflīsi uses the term abgine for glass used as a polishing tool. Sometimes even a person’s bare hands were used to smoothen the surface of paper. A hard and smooth base made of flint (čaqmāq) was also employed, and a wooden board was used as the base for burnishing and sizing paper.

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26 Bloom 2001, 68f.
27 Wulff 1976, 237.
28 Gum tragacanth is called katirā in Persian. It is a natural gum obtained from the dried sap of several species of Middle Eastern plants of the genus Astragalus. The sap is drained from the root and stems of the plant and then dried.
29 Asphodel belongs to the family of the Liliaceae. In Iran, a glue called seri is made from the bulbs of this plant, which are first dried and then pulverised. The powder forms a strong glue when mixed with cold water.
Vegetable base sizes
The first category is vegetable base sizes, which include types of starch, gum, plant mucilage, fruit juice and sugar.

1. Starch (nešāste)
A general term for starch, nešāste, which we believe to be rice starch, was mentioned in seven treatises. The process of sizing with starch (nešāste) was discussed in detail in Bayān al-Ṣenā by Teflisi, Jowhar-e Simi by Simi Neyšapuri, Serāt al-Ṣoṭur by Soltān Ali Mašhadi, Favāyed al-ḵoṭuṭ by Bokārī, Ādāb al-Maṣq by Bābā Shāh-e Isfahāni and Resāle dar Bayān-e Kāḡaḏ Morakkab va Hall-e Alvān and Resāle dar Bayān-e Tariqe Ye Sāḵtan-e Morakkab va Kāḡaḏ-e Alvān by anonymous authors. The eminent calligrapher Soltān Ali Mašhadi, for example, devoted several couplets of his treatise on calligraphy, Serāt al-Ṣoṭur, to sizing and glazing paper by hand, as shown here:

Prepare the size (āhār) from starch learn these words from an old man.
First make a paste, then pour in water, then boil this on a hot fire for a moment,
Then add some glue (seriš) to thin starch, strain it [so that it is] neither too thin nor too thick,
Spread it on paper and make sure, that the paper does not move from its place.
When you are applying size to your paper, moisten the paper slightly with water, carefully.

It is worth mentioning that Serāt al-Ṣoṭur, Favāyed al-ḵoṭuṭ and Resāle dar Bayān-e Ḵaṭṭ va Morakkab va Kāḡaḏ va Sāḵtan-e Ranghā specifically advise mixing asphodel glue (seriš) to the starch paste. To prepare layered paper, Simi Neyšapuri describes the technique using starch size thus:

Cook some starch and size paper. Pieces of sized paper can stick together in such a way that they become one sheet. This can then be burnished and written on. Calligraphy on this paper is legible and beautiful, and is as good as it is on soltānī paper.34

Wheat starch (nešāste-ye gandum):
This is specified in Golzār-e Ṣafā by Ali Seyrafi and in Ḵaṭṭ va Morakkab by Hossein Aqili Rostamdari. Ṣaḵṭ va Morakkab describes the technique as follows:

To size a piece of paper, take some wheat starch, filter it and then cook it to make a paste. Then take a wooden board and cover it with felt (namad) or a muslin cloth. Take two bowls; pour the starch into one and some water into the other. Moisten a ball of cotton with starch and rub it over the paper. Finally, take another piece of clean cotton ball, moisten it with water and rub it over the starched paper. The paper can be sized this way.

In Golzār-e Ṣafā, Seyrafi describes the process beautifully in the form of a poem:

34 The term soltānī means ‘royal’ in Persian. According to Bābā Shāh-e Isfahāni (tenth century Hijra/sixteenth century CE) in his treatise Ādāb al-Maṣq, soltānī is high-quality paper, which is also known as dolatābādī. In his book Kāḡaḏ dar Zendegi va Farhang-e Īrānī (1390 Hijra/2011 CE), Iraj Aflar says that soltānī paper refers not only to dolatābādī paper but also to samarqandī paper – the high-quality paper made in Samarqand in the eighth century. See Barkeshli 1998, 102, table 1.
قدحی آب همان پیش آور
کاغذ ای سرو روان ده آهار
پس به آهار بمالش چالاک
صفحه زین قاعده هموار شوی

که همان مصلح آهار شوی

Take the best-quality white rice, rub it with salt and wash it until it is clean and the taste of salt disappears. Then add some water and keep it for a whole day until it becomes soft and dissolves by rubbing. Place it in a mortar (hāvan) and grind it together with water. Put the soft parts into a clean pot so that it all comes together. Then filter it and put it into a large copper vessel. Boil it on a slow fire; stir it with a wooden stick till it becomes a paste. Let it get cold. Spread the paper on the wooden board. Size the paper with a clean cloth moistened with the paste. Spread a piece of cloth in the sun and put the paper over it till it dries. Finally, burnish the paper until it is very smooth. Dyes can be added to the paste to get coloured paper. By using this method, nobody will be able to distinguish this paper from Baghdadi paper.

Simi and an anonymous person in Resāle dar Bayān-e Kāḡaḏ Morakkab va Ḩall-e Alvān describe a number of sizing materials that could be used when the paper is very thin and the pen used for writing gets stuck and is unable to move over it smoothly. One of the sizing materials they recommend for use is oil-free rice porridge (ḥalim-e berenji bi ṭoghan).

2. Gum:
Two other sizing materials mentioned in the historical treatises that fall into this category are gum arabic (samḡ-e arabi) and gum tragacanth (katirā).

Gum arabic (samḡ-e arabi):
This substance is mentioned in Jowhar-e Simi, Resāle dar Bayān-e Kāḡaḏ Morakkab va Ḩall-e Alvān, Golzār-e Ṣafā, Ḥaṭṭ va Morakkab and Resāle dar Bayān-e Tariqe-Ye Ṣāḵtan-e Morakkab va Kāḡaḏ-e Alvān. According to these sources, gum arabic is a very good sizing material and is suitable for writing. Hosseini Aqili Rostamdari says in Ḥaṭṭ va Morakkab:

نوع دیگر آن که صمغ را آب کند وکاغذ را بدان آهار کند

... and furthermore dissolve gum arabic in water and size the paper with it.

In one of his couplets in Golzār-e Ṣafā, Seyrafi mentions gum arabic for the last sizing:

attributes of different sizings

my dear: my eyes and my ears are open to you, i always long for your grace.

the perfect kind of sizing is a fine clear extract [starch] made of wheat.

cook (boil) the wheat extract many times and filter it and use it repeatedly.

while you size [the paper], oh moon-faced one, hear from me the attributes of that heart attracting one.

bring correctly measured boards and place over them felt or muslin cloth.

fill a bowl with sizing up to the rim and bring forward another bowl filled with water.

take an amount of sizing with a piece of cotton, oh gracefully flowing cypress tree, apply sizing on paper.

make wet another piece of clean cotton and rub it over the sized paper.

hence you become a restorer of sizing and the page becomes smooth with this foundation.

rice starch (nešāste-ye berenj):

rice was specified in various sources – Teflisi’s Bayān al-Ṣenāʿat, Simi’s Jowhar-e Simi and the anonymous Ḥaliyyat al-Ketāb (the tenth chapter of Bayān al-Ṣenāʿat). In Ḥaliyyat al-Ketāb, the process of making starch paste from rice and using it as a sizing material is stated as follows:

 Attributes of Different Sizings

My dear: my eyes and my ears are open to you, I always long for your grace.

The perfect kind of sizing is a fine clear extract [starch] made of wheat.

Cook (boil) the wheat extract many times and filter it and use it repeatedly.

While you size [the paper], oh moon-faced one, hear from me the attributes of that heart attracting one.

Bring correctly measured boards and place over them felt or muslin cloth.

Fill a bowl with sizing up to the rim and bring forward another bowl filled with water.

Take an amount of sizing with a piece of cotton, oh gracefully flowing cypress tree, apply sizing on paper.

Make wet another piece of clean cotton and rub it over the sized paper.

Hence you become a restorer of sizing and the page becomes smooth with this foundation.

Rice starch (nešāste-ye berenj):

Rice was specified in various sources – Teflisi’s Bayān al-Ṣenāʿat, Simi’s Jowhar-e Simi and the anonymous Ḥaliyyat al-Ketāb (the tenth chapter of Bayān al-Ṣenāʿat). In Ḥaliyyat al-Ketāb, the process of making starch paste from rice and using it as a sizing material is stated as follows:
rice mucilage, however, only the mucilage part is collected from the upper part of the boiled rice and then used as sizing material. In some of his couplets on sizing material in Golzār-e Šafā, Seyrafi mentions rice mucilage as being the fifth material for sizing after starch and fish glue:

... the last one is gum arabic, these are all used as sizing.

Gum tragacanth (katirā):
Katirā is known to have been employed as a sizing material, but in the Persian sources we studied, only Teflisi mentions its use for this purpose.

3. Asphodel (serīš):
This is a well-known vegetable glue which has already been mentioned above and was traditionally used for binding books in Iran; see Sultan Ali Mashhadi in Šerāt al-Ṣotūr and Moḥammad Boḵāri in Favāyed al-Ḵoṭuṭ. As mentioned above in the rice-starch recipe, Soltān Ali Mashhadi devotes several couplets of his treatise on calligraphy, Šerāt al-Ṣotūr, to sizing and glazing paper by hand. In the couplet, he mentions serīš being added to rice starch to make the size for paper as follows:

پس لعاب سرش به او کن ضم       صاف سازش نه نرم و نه محکم
Then add to thin starch some glue (serīš), strain it [so that it is] neither too thin nor too thick.

4. Plant mucilage (loʿāb):
Mucilage is a gummy or gelatinous substance produced in certain plants by the action of water on the cell wall, as in the seeds of quinces, flax, etc. It is also a polar glycoprotein and an exopolysaccharide. Mucilage in plants plays a role in the storage of water and food, seed germination and thickening of membranes. A number of kinds of mucilage were used as sizing materials to size paper in Iran according our historical analysis. Jowhar-e Simi, Resāle dar Bayān-e Kāḡaḏ Morakkab va Hall-e Alvān, Golzār-e Šafā, Kaṭṭ va Morakkab and Resāle dar Bayān-e Tariqe-ye Sāḵtan-e Morakkab va Kāḡaḏ-e Alvān state a number of sizing materials made from plant mucilage, but the descriptions are not as detailed as that of starch.

Rice mucilage (loʿāb-e berenj):
In Golzār-e Šafā and Resāle dar Bayān-e Tariqe-ye Sāḵtan-e Morakkab va Kāḡaḏ-e Alvān, mucilage from rice is mentioned as a sizing material. The difference between rice mucilage and rice starch is that in the case of rice starch, the whole rice is cooked and used as a sizing material. As for

**Fleawort seed (espāghol, esfarze, qeṭūnā):**
Fleawort seeds are mentioned in the following sources: Jowhar-e Simi, Resāle dar Bayān-e Kāḡaḏ Morakkab va Hall-e Alvān, Golzār-e Šafā, Kaṭṭ va Morakkab and Resāle dar Bayān-e Tariqe-ye Sāḵtan-e Morakkab va Kāḡaḏ-e Alvān. The techniques stated in the first four sources are the same; they only differ in the duration the paper is dipped in mucilage. Golzār-e Šafā and Kaṭṭ va Morakkab use the term qeṭūnā for these seeds. Hossein Aqili Rostamdari explains the process thus in his book Kaṭṭ va Morakkab:

نوعی دیگر بذر قطونا را در آب ریزند تا لعاب بدهد بعد از آن کاغذ را در لعاب او بگذارند یک ساعت، و بیرون آورند.
Pour some fleawort seeds into water [and leave them in it] until you get some mucilage. Leave the paper in the mucilage for one hour and then take it out.

In Jowhar-e Simi and Resāle dar Bayān-e Kāḡaḏ Morakkab va Hall-e Alvān (ninth century Hijra), the duration the paper is dipped in fleawort-seed mucilage is shorter. The sources say: ‘Size a sheet of paper with mucilage from fleawort seeds all at once, then let it dry’, but Simi stresses that the mucilage from fleawort seeds must be filtered first and then used. In some of his couplets on sizing material in Golzār-e Šafā, Seyrafi, after discussing rice starch and fish glue, mentions that there are six more sizing materials: first of all, fleawort-seed mucilage; second, sweet melon juice; third, cucumber seed; fourth, grape syrup; fifth, rice mucilage; and last of all, gum arabic. In the first three couplets, he advises the reader on using fleawort seed as the best material for sizing after starch and fish glue:

35 Fleawort is Plantago psyllium.
In the sources, the term ‘dye’ (rang) is used rather than ‘size’ (āhār). In the last source mentioned, for example, it says:

کاغذ را بدان رنگ کند خط نم کند و دیگر خطمی را یک شب و یک روز بری خوب آید.

Soak marshmallow (in some water) for a night and a day. Dye the paper with it. The calligraphy on it will be nice.

Referring to marshmallow mucilage, Jowhar-e Simi and Resāle dar Bayān-e Kāḡaḏ Morakkab va Hall-e Alvān state:

Keep marshmallow seeds in water for a night. Then dye the paper with the mucilage. This process is highly appreciated, it softens the paper, and the calligraphy stands out well on it.

Mucilage from myrtle seeds (toḵm-e mord):

This is only mentioned in Jowhar-e Simi and Resāle dar Bayān-e Kāḡaḏ Morakkab va Hall-e Alvān. The second source explains the process as follows:

The paper that is of a turquoise colour and prevents the pen from moving smoothly on it [during writing] can be fixed by sizing [paper] with sweet melon juice or Egyptian rock sugar, mucilage from myrtle seeds, mucilage from fleawort seeds or oil-free rice mucilage, which all make the paper strong. And when the paper is burnished, it is like a mirror.

5. Fruit juice:

It is interesting to note that in the historical treatises, fruits such as melons and grapes are used as sizing material.
Juice of a sweet melon (karboze):
This juice is mentioned as a good sizing material in Jowhar-e Simi, Resâle dar Bayân-e Kâqad Morakkab va Hall-e Alvân, Golzâr-e Şafâ, Kaṭṭ va Morakkab and Resâle dar Bayân-e Tariqe-ye Sâḵtan-e Morakkab va Kâqad-e Alvân. Seyrafi mentions melon juice as the next-best material after starch and fish glue in Golzâr-e Şafâ:

... Second is sweet melon, its extract is size to adorn [paper].

After mentioning fleawort in his work Kaṭṭ va Morakkab, Hossin Aqili Rostamdari continues:

... and furthermore, they take the juice of a sweet melon (karboze) and dip the paper in it for sizing.

Grape syrup (šireye-angur):
Grape syrup is mentioned as a sizing material in Jowhar-e Simi, Resâle dar Bayân-e Kâqad Morakkab va Hall-e Alvân, Golzâr-e Şafâ and Kaṭṭ va Morakkab. Seyrafi discusses grape syrup as the third material for sizing after starch and fish glue in his couplets on sizing materials in Golzâr-e Şafâ. The source Resâle dar Bayân-e Kâqad Morakkab va Hall-e Alvân mentions grape syrup as a sizing material and stresses the point that the grapes should be seedless. In Kaṭṭ va Morakkab, Hosseini Aqili Rostamdari maintains:

... and moreover, grape syrup is filtered and applied on paper as size.

Animal base sizes
The next category is animal base sizes; animal glue obtained from fish is actually the only size found in the recipes in this category.

Fish glue (sirišum-e mâhi):
This type of size is mentioned in Jowhar-e Simi, Resâle dar Bayân-e Kâqad Morakkab va Hall-e Alvân, Golzâr-e Şafâ, Kaṭṭ va Morakkab and Resâle dar Bayân-e Tariqe-ye Sâḵtan-e Morakkab va Kâqad-e Alvân, where its use is described as follows:

It is possible there was no deliberate intention to introduce these sizing materials as mixed sizes since the above text is quite similar to Jowhar-e Simi and Resâle dar Bayân-e Kâqad Morakkab va Hall-e Alvân. Myrtle is mentioned as an extract (āb-e mord) in the second source, whereas in the first source, it is in the form of myrtle seeds (toḵm-e mord).
Soak a small amount of white-fish glue \( [sirišum] \) in water. Change the water and fill [the bowl] with fresh water for three days until it clears thoroughly. Heat the \( sirišum \) till it melts, then filter it with a piece of muslin cloth. Apply the fish glue on paper as sizing material. Let it dry in the sun carefully. They burnish [it] and then they write.

Ali Seyrafi describes the process as follows in his treatise \textit{Golzār-e Ṣafā}:

Scientific analysis

In order to investigate the presence of sizing materials mentioned in historical literary references, the research was carried out in two stages. In the first of these, the sizing materials that were identified through historical analysis were prepared according to recipes for fingerprint data collection. In the second stage, a series of sample analyses were conducted on the sizing materials of eleven historical Persian and Indian miniature paintings, illuminated manuscripts belonging to the Iran Bastan Museum and private collections from the sixteenth (Safawid) to nineteenth (Qajar) centuries.\textsuperscript{39}

Materials and techniques

In the first stage, sizes were identified from our historical analysis. The materials were categorised as proteinaceous materials, which include animal glue, starch from rice or wheat, vegetable gum, mucilage from plants and seeds, types of fruit juice, and sugar syrup. Based on each category identified from the historical treatises, ingredients were collected from the local markets in Iran, viz. fish glue, rice and wheat starch, asphodel (\( seriš \)), fleawort seeds, cucumber seeds, melon seeds, marshmallow seeds, raw rice, grape syrup, melon syrup and sugar syrup. The sizings were prepared on the basis of the historical recipes. The duration of boiling, cooking and soaking the materials followed the recipes’ specifications as much as possible. However, since the exact length of time was not specified in the recipes, the experiments needed to be repeated several times in order to get the consistency suitable for sizing. Handmade paper was selected from the conservation laboratory of the Iran Parliament (Congress) Library in Tehran and pieces of paper were divided into eleven groups for each sizing material under investigation. In each group, the pieces were divided into eight items of 2.5 cm\(^2\) in size for the sample experiments. Each eight-item group was then divided into two sub-groups: four paper samples for sizing using a dipping technique and four other paper samples for sizing with a brush. In the case of the dipping technique, the samples of paper were sized for four different lengths of time: 15, 30, 45 and 60 seconds. As for the brushing technique, the samples of paper were sized using a soft brush and one to four coats of size were applied. The paper samples were sized with the different materials identified in the recipes, left to dry at room temperature and then individually burnished with an agate stone on a flat wooden board.

In the second stage of the investigation, the large collection of sizing materials that was prepared on the basis of the historical recipes was compared with the spectra of original samples of paper. An analysis of the sizing materials used in the original samples was carried out using a staining method and Fourier transform infrared spectrometry (FTIR). The spectrometry was conducted with a Nicolet 510 P instrument equipped with a microscope attachment. Sample preparation

\textsuperscript{38} Barkeshli 1997, 338, 420-422.

\textsuperscript{39} Barkeshli, 2003, 2005.
was done by mixing KBr and the unprepared sample (100:1). Identification of the materials in the samples was achieved by comparing the infrared spectrum with the reference spectra via recognition of specific bands.

Starch was detected on paper by the formation of the characteristic blue colour when a dilute aqueous solution of iodine-potassium iodide was added (see appendix B, table 2).

Results and discussion

The intention of preparing sizes based on historical recipes in the first phase was to collect data for a further analysis of original samples in order to identify the sizing material in stage two. However, our research in the first phase showed that each sizing material has its own particular properties and gives a certain effect to the paper. Further investigation is required here to collect more detailed data. Our visual and physical observations will hopefully be valuable for future research. We found that starch paste gives more body to paper and makes it firmer. In contrast, plant mucilage – especially from cucumber seed – gave the paper a lighter body and made it softer than the effect obtained using starch paste. Fruit and sugar syrups gave more shine to the surface of the paper we examined and made it stiffer compared to plant mucilage. As for vegetable and animal glue, they both added a lustre to the paper, but animal glue made the paper stiffer than vegetable glue did.

In terms of drying, the sizing material sometimes took a while to dry, depending on the duration of dipping and the number of layers of it that had been applied. The drying process was prolonged if the dipping or application process was repeated during the sizing procedure. It is interesting to note that cucumber-seed mucilage was what dried the fastest and paper sized with it was also easier to burnish than with other sizing materials.

In the second stage, our investigation showed that out of six categories of sizing materials recommended, mucilage from cucumber seeds was the most common sizing material on the paper samples identified by the FTIR method (see fig. 9). Out of the nine Persian miniature paintings and illuminated manuscripts examined, one of the sizes used was starch, seven were cucumber-seed mucilage and one was a mixture of tragacanth and cucumber seed. The reason why cucumber-seed mucilage was used more than other recommended sizes needs more investigation. According to our observations, paper sized with cucumber-seed mucilage gave better results in terms of aesthetics, giving the paper a lighter body and softer look. In terms of the sizing process, it dries faster and is easier to burnish. Moreover, I believe that there may well have been a reason behind it being recommended for sizing since cucumber-seed mucilage is less prone to attack by micro-organisms than starch, vegetable gum, animal glue, fruit extracts and sugar due to its nature and chemical composition. This assumption will be reported on in more detail in future.
Conclusion

There is a huge amount of information that can be found in historical treatises and recipes relating to the art of book-making in Iran. Most of these literary references are written in the form of poetry or mystical language. This paper has tried to show how it is possible for researchers to discover the reasons for authors choosing particular ingredients, which can be explained in terms of chemistry, and has presented some examples to show how scientists should look at such pieces of information. The research outlined here focused on introducing the author’s theoretical and methodological approach by presenting three exemplary case studies.

To this end, twenty-four Persian treatises from the thirteenth to the nineteenth century were selected and their texts were studied in a bid to understand the techniques and ingredients explained and recommended by different masters in the art of calligraphy and bookmaking. Many of these texts are written in poetic language; the terms that were picked for them were used and understood in a specific way at the time of writing. The information we sought was collected and categorised in three areas: pigments used in illumination and painting, dyes used in paper-dyeing, and sizing materials used to prepare paper. From the huge amount of data collected in these three areas, three ingredients were selected as case studies to show just how modern science can contribute to an understanding of the reasons for using certain ingredients or certain techniques, or even using certain proportions of substances that were recommended.

The first case study presented in order to introduce our theoretical and methodological approach to material technology concerned the techniques used in conjunction with corrosive verdigris pigment, involving the addition of saffron to prevent the pigment from charring the paper. Our research showed that saffron is a very strong buffer and acts as an inhibitor, stopping the destructive effect that verdigris would otherwise have on paper.

The second case study presented was concerned with the art of paper-dyeing. In this part, we specifically focused on henna to see whether the ratio of 1:10 advised by master calligraphers had a factual reason behind it. Our research showed that henna has a fungicidal effect and can reduce the growth of *aspergillus flavus* fungus when used exactly in the advised ratio.

The third case study presented here focused on the sizing materials used in medieval and early modern Iran. Our study based on historical recipes showed that Iranians used a considerable range of materials in the sizing process. However, our scientific investigation revealed that only cucumber mucilage, starch and tragacanth gum were actually used in the original manuscripts. Moreover, our study showed that cucumber-seed mucilage was used more often than the other materials under investigation. The precise reason for this is still being investigated. However, I believe the rationale for this choice to be the notion that a microbiological attack on sized paper could be reduced due to the nature and chemical composition of cucumber-seed mucilage. This is a matter I am still investigating.

Our investigation has shown that art and applied science have been closely linked in the course of Iran’s rich history. Moreover, we have been able to show that Iranian artists and masters of calligraphy had extensive knowledge of chemistry and the nature of the materials they employed in their work. They were also able to use mystical literary references as a means of passing on their knowledge to their pupils.
APPENDIX A:


2. Ali Hosseini, *Morakkab Sāzi va Jeld Sāzi* (‘Ink-making and Binding’), part of the second, third, ninth, thirteenth and sixteenth chapters from *Kašf al-Ṣanāyeʿ* (attributed to the Qajar period), Tehran University Library copy, No. 2261, Tehran, Iran; Āyatollah Marʿaši Library copy, No. 4917, Qom, Iran.

3. Alkašfi, *Bayān al-Ṣanāʿat* (‘Descriptions of Crafts’), (attributed to the Qajar period), personal library, A. M. Tākestānī, Tehran, Iran.

4. Anonymous, *Resāleh dar Bayān-e Kāḡad Morakkab va Ḥall-e Alvān* (‘A Treatise about Paper, Ink and Dissolving Dyes’), (early or mid-ninth century Hijra/fifteenth century CE), Parliament Library copies, No. 1 and No. 4767 (1100 Hijra), Tehran, Iran.

5. Anonymous, *Ḥaliyyat al-Ketāb* (‘Lawfulness of Writing’), (attributed to the Safawid period) in *Majmuʿah al-Ṣanāʾiʿ* (thirtieth chapter), Tehran University Central Library copy, No. 3875 (1005 Hijra/1596/1597 CE), Tehran, Iran; Āyatollah Marʿaši Library copy, No. 4917, Qom, Iran.


10. Anonymous, *Resāleh dar Bayān-e Ḵaṭṭ va Morakkab va Kāḡad va Sāktan-e Ranghā* (‘A Treatise about Calligraphy, Ink and Making Dyes’), (attributed to a later date, probably thirteenth century Hijra/nineteenth century CE based on Safawid and Timurid masters’ recipes), Malek National Library copy, No. 4211, Tehran, Iran.


12. Bābā Shāh-e Isfahani (tenth century Hijra/sixteenth century CE), *Ādāb al-Mašq* (‘Manners of Writing’), Malek National Library copy, No. 526 (1271 Hijra/1854/1855 CE); No. 2284 (1284 Hijra/1867/1868 CE), Tehran, Iran; Āstān Qods Rażavi Central Library copy, No. 130 (1292 Hijra/1875 CE), Mashhad, Iran.

13. Hossein Aqili Rostamdari (c. 930–984 Hijra/c. 1523–1577), *Ḵaṭṭ va Morakkab* (‘Calligraphy and Ink’), Āstān Qods Rażavi, copy No. 2033, Mashhad, Iran; British Museum, copy No. 3648, London, UK; Tehran University Central Library copy (microfilm) No. 4021, Tehran, Iran.


**APPENDIX B:**

Table 1:
Sizing materials on selected paintings collected from the Iran Bastan Museum Collection and from private collections.

<table>
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<th>Origin</th>
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<th>Cuc</th>
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**Key to sizings:**

- **Sta** = Starch
- **Cuc** = Cucumber’s Seeds
- **Tra** = Tragacant (katirā)

**Key to object:**
- **I.M.** = Illuminated Manuscript
- **M** = Miniature

**Key to identification methods:**

- **s** = Determination of starch by staining the paper with iodine-potassium iodide solution.
- **f** = Identification of sizing materials in the sample is obtained by comparing the infra red spectrum with reference spectra or by reorganizing specific bands.

The following sizing materials were investigated without traces found: fish glue, gum arabic, ispagol, sweet melon, rice mucilage, grape syrup, sugar syrup, and myrtle juice.
Table 2:
Pigments collected from traditionally produced art objects and paintings in private collections and from selected paintings from the Iran Bastan Museum Collection.

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Key to Subjects
I.M. = Illuminated Manuscript
M = Miniature
Pb = Paintbox
P.P. = Paint Palette

Key to Pigments
Br = Brown Earth
Car = Carbon
Cha = Chalk
Cog = Copper Green
Gld = Gold
Idg = Indigo
Ind = Indian Yellow
Ldw = Lead White
Mal = Malachite
Org R = Organic Red
Ozp = Orpiment
Rd = Red Earth
Rld = Red Lead
Rub = Rubarb
Tiw = Tin White
Ver = Vermilion
Ult = Ultramarine

Key to Identification Methods
f = Identification of sizing materials in the sample is obtained by comparing the infra red spectrum with reference spectra or by reorganizing specific bands.
m = Appearance by transmitted light on a microscopic slide observed by polarized light microscopy.
u = Fluoresces in long-wave ultraviolet light.
x = Crystalline structure by x-ray powder diffraction.

*Saffron was mixed with verdigris (Cog).
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