Technical Knowledge in Europe, 1200-1500 AD

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Edited by
Ricardo Córdoba de la Llave
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FOREWORD

This book compiles a series of works about the development of scientific and technical knowledge in Europe between the thirteenth and sixteenth centuries, with a particular focus on the Iberian Peninsula.

Many of the works deal with technical and professional knowledge at the workshop level, including a wide variety of trades, such as hide tanning, metallurgy, artistic techniques, glassmaking, and architecture. These works, which are largely based on the evidence provided by the written record, pay special attention to the content of fifteenth and sixteenth-century recipe books and technical treatises.

These contributions demonstrate the considerable scientific and technical sophistication of crafts such as coin minting and the assaying of precious metal, cloth and silk dyeing, and manuscript illumination. These technical demands suggest that the written word was a basic tool for the transmission of the associated knowledge, contributing to the emergence of technical literature in the shape of recipe books and technical treatises, which conveyed comprehensive information about these techniques and which can now be used to gauge scientific and technical knowledge in the Middle Ages.

These texts, in manuscript form for the most part, are relevant for a better understanding of knowledge transfer. Although it is widely believed that most craftspeople were illiterate, learning their trade empirically, the fact remains that many trades had technical manuals that contributed to transmit new techniques and ensure the technical proficiency of practitioners.

Another important group of chapters focuses on research undertaken with artistic and archaeological material remains dated to the medieval and Early Modern periods, an increasingly important approach for the full understanding of technical and scientific knowledge in the past. This includes research on actual production areas (dyeing houses, forges, tanneries, mills) and the analysis of tools and other forms of material culture employed in production. Recent advances in the use of physical-chemical analyses on historical materials (metal, glass, pottery) are increasing our understanding about not only their chemical composition but also knowledge transfer, commercial networks, and technical innovation over time; this is an essential complement to the information provided by coetaneous written sources.

The volume deals with all these issues (analysis of technical manuscripts and recipe books, the archaeological research of production areas and archaeometric analyses), presenting a holistic and comprehensive perspective on technical knowledge during the Middle Ages. It compiles the contributions to the international conference El conocimiento técnico en Europa (siglos XIII – XVI): De las fuentes escritas a las evidencias arqueológicas, held in Córdoba, Spain, in September 2015. The conference was organized by the History Department, University of Córdoba, with the support of the research project El Conocimiento Científico y Técnico en la Península Ibérica (siglos XIII–XVI), funded by the Spanish Ministry of Economy and Competitiveness. The conference brought together specialists in medieval technological and technical knowledge and their study through historical and archaeological sources. Its ultimate aim was to approach medieval technical knowledge from the complementary perspective offered by a wide array of research methodologies, in order to develop novel insights into the subject matter. As such, some of the contributions presented various research methodologies (Sylvie Neven, Didier Bousseuil, David Igual), while others delved into the analysis of technical manuscripts (Córdoba, Criado) and archaeological (Arribet, Bernardi), archaeometric (Duckworth, Melo), and experimental perspectives (Díaz).

All contributions come from specialists based in European universities, including Newcastle (Duckworth, Govantes-Edwards), Liège (Neven), Lisbon (Melo, Díaz), Tours (Bousseuil), Paris I (Bernardi, Arribet), Paris VIII (Verna, Dillmann), Madrid (Kroustallis), and Córdoba (Criado, Varela, López, Córdoba), a reflection of the volume's pan-European approach.

The volume's main objective is to emphasize different approaches and perspectives in the analysis of medieval technical and technological knowledge and reach equally wide-ranging and complementary conclusions. The work will be of use to those interested in the history of science and technology, production in various economic sectors, medieval trades, artistic technologies and the dissemination and transmission of technical knowledge. It is targeted at a university-based audience, including lecturers, students, and researchers, but will also be of interest to a less specialized public interested in the development of science and technique in medieval and Renaissance Europe.

Ricardo Córdoba de la Llave
Javier López Rider
Córdoba, February 2022

CHAPTER ONE

THE PRODUCTION OF COLOUR IN MEDIEVAL ILLUMINATED MANUSCRIPTS

MARIA JOÃO MELO, PAULA NABAIS, AND TATIANA VITORINO

Abstract: This article highlights technical aspects relevant to the experimentation contained within a remarkable Portuguese Hebrew text, which was copied in the fifteenth century: *The Book on How to Make all the Colour Paints for Illuminating Books*. Ten years of systematic research has allowed us to conclude that the descriptions of making colours and paints contained within this text are brief and precise, and that in many cases these descriptions include additional information on the most important steps, which can be crucial to the practitioner.

Keywords: colour paints; medieval; illuminated manuscripts; Hebrew Bibles.

1. Introduction

One of the long-term objectives of our research on the production of medieval pigments and paints is to find better ways to preserve and protect medieval manuscripts and their illuminations.[1] To further this objective, we have researched several medieval technical sources, especially a manuscript

[1] See M. J. Melo et al., "The Colour of Medieval Portuguese Illumination: An Interdisciplinary Approach," *Revista de História da Arte* 1 (2011): 147–69; M. J. Melo, R. Castro, and M. A. Miranda, "Colour in Medieval Portuguese Manuscripts: Between Beauty and Meaning," in *Science and Art: The Painted Surface,* eds. A. Sgamellotti, B. G. Brunetti, C. Miliani (Cambridge: RSC Publising, 2014), 170–92; M. A. Miranda, and M. J. Melo, "Secrets et découvertes, en couleur, dans les manuscrits enluminés," in *Portuguese Studies on Medieval Illuminated Manuscripts*, eds. M. A. Miranda and A. Miguélez Cavero (Turnhout: Brepols, 2014), 1–30.

titled *The Book on How to Make all the Colour Paints for Illuminating Books* (henceforth *The Book of All Colours*),[2] as well as texts that provide information on how to make colours using insects and plants (organic pigments).[3] These organic colourants were commonly used by medieval illuminators, but they are potentially more vulnerable than mineral-based pigments (inorganic pigments). Their identification, at a molecular level,[4] is challenging and evaluating whether the changes affected the original hue is one of our main research aims.[5]

This article presents the main results of the work undertaken by an interdisciplinary team led by Maria João Melo, chemist and conservator, and Maria Adelaide Miranda, art historian and specialist in medieval illuminations; many other experts and disciplines have contributed to our results.

Our methodology is characterized by a "hands-on" approach, accompanied by a full molecular characterization of colourants and pigments.[6] In this way, by combining chemical characterization methods

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[2] M. J. Melo, and R. Castro, *O livro de como se fazem as cores: Medieval Colours for Practitioners* (online edition, 2016), http://www.dcr.fct.unl.pt/LivComoFazemCores. We have used Devon Strolovitch's text, which was published for the first time as part of his PhD thesis, and more recently as D. L. Strolovitch, "O libro de komo se fazen as kores das tintas todas (Transliteration)," in *The Materials of the Image: As Matérias da Imagem*, ed. L. U. Afonso (Lisbon: Cátedra de Estudios Sefarditas "Alberto Benveniste" da Universidade de Lisboa, 2010), 213–36.

[3] R. Castro, A. Miranda, and M. J. Melo, "Interpreting Lac Dye in Medieval Written Sources: A Past Knowledge Within Portuguese Illuminations," in *Sources on Art Technology: Back to Basics*, eds. S. Eyb-Green, J. H. Townsend, J. K. Atkinson, S. Kroustallis, K. Pilz, I. van Leeuwen (London: Archetype Publications, 2016), 88–99.

[4] M. J. Melo, and A. Claro, "Bright Light: Microspectrofluorimetry for the Characterization of Lake Pigments and Dyes in Works of Art," *Accounts of Chemical Research* 43 (May 2010): 857–66; R. Castro et al., "Combining SERS and Microspectrofluorimetry with Historically Accurate Reconstructions for the Characterization of Lac Dye Paints in Medieval Manuscript Illuminations," *Journal of Raman Spectroscopy* 45 (November 2014): 1172–9; M. J. Melo et al., "A Spectroscopic Study of Brazilwood Paints in Medieval Books of Hours," *Applied Spectroscopy* 68 (2014): 434–44; M. J. Melo et al., "Organic Dyes in Illuminated Manuscripts: A Unique Cultural and Historic Record," *Philosophical Transactions of the Royal Society A* 374 (December 2016): 1–20.

[5] M. J. Melo et al., "Colour Degradation in Medieval Manuscripts," *Microchemical Journal* 124 (January 2016): 837–44.

[6] A. Claro, *An Interdisciplinary Approach to the Study of Colour in Portuguese Manuscript Illuminations* (Lisbon: Doctoral dissertation, Universidade Nova de Lisboa, 2009) http://run.unl.pt/handle/10362/11506; C. Miguel, *Le Vert et le Rouge:*

and experimental archaeology techniques, the production of medieval pigments and paints was brought back to life in the laboratory.[7] The accuracy of the reproduction of medieval pigments must be tested by applying advanced methods of analysis.[8] These methods were used to identify all the components present in a medieval pigment, including colourants, binders, varnishes, and other additives. Some of these components are invisible to the naked eye but are essential for the applicability and durability of the medieval paint. In this way, when we claim to have reproduced a medieval pigment, we mean that this pigment has been reproduced on an aesthetic but also molecular level (including morphology); the description of the colour must therefore include both its appearance to the naked eye as well as spectral data and other information essential for the pigment's molecular characterization.[9] In the reconstruction of the pigments, we made use of chemical "shortcuts," provided that these did not compromise the historical accuracy of our study.

A Study on the Materials, Techniques and Meaning of the Green and Red Colours in Medieval Portuguese Illuminations (Lisbon: Doctoral dissertation, 2012), http://run.unl.pt/handle/10362/9304; R. Castro, *The Book of Birds in Portuguese Scriptoria: Preservation and Access* (Lisbon: Doctoral dissertation, 2016), http://hdl.handle.net/10362/21481.

[7] "'O livro de como se fazem as cores': Medieval Colours for Practitioners," Nova School of Science and Technology, https://www.dcr.fct.unl.pt/LivComoFazemCores

[8] C. Miguel et al., "A Study on Red Lead Degradation in a Medieval Manuscript Lorvão Apocalypse (1189)," *Journal of Raman Spectroscopy* 40 (December 2009), 1966–73; S. Mas et al., "Screening and Quantification of Proteinaceous Binders in Medieval Paints Based on μ-Fourier Transform Infrared Spectroscopy and Multivariate Curve Resolution Alternating Least Squares," *Chemometrics and Intelligent Laboratory Systems* 134 (December 2014): 148–57; A. Miguélez Cavero et al., "Beatus Manuscripts Under the Microscope: The Alcobaça Beatus and the Iberian Cistercian Tradition Revisited," *Journal of Medieval Iberian Studies* 8, no. 2 (September 2016): 217–51; C. Barreira, M. J. Melo, R. Araújo, and C. Casanova, "Through the Eyes of Science and Art: A Fourteenth-century Winter Breviary from Alcobaça Scriptorium," *Journal of Medieval Iberian Studies* 8 (September 2016): 252–82; P. Nabais et al., "Singing with Light: An Interdisciplinary Study on the Medieval Ajuda Songbook," *Journal of Medieval Iberian Studies* 8, no. 2 (September 2016): 283–312.

[9] C. Miguel et al., "The Alchemy of Red Mercury Sulphide: The Production of Vermilion for Medieval Art," *Dyes and Pigments* 102 (March 2014): 210–17; T. Vitorino et al., "New Insights into Brazilwood Lake Pigments Manufacture through the Use of Historically Accurate Reconstructions," *Studies in Conservation* 61 (March 2016): 255–73.

These historically accurate pigments are critical for studies on the deterioration processes at play in medieval manuscripts, as well as when testing new conservation treatments.

1.1. Context and importance of the historical reproduction of a medieval pigment

For the reproduction of medieval pigments, we followed the processes described in *The Book of All Colours* as accurately as possible; accuracy is used in the sense of "the accuracy of a measurement is its closeness to the true value. "[10]

During the first stage of research, we focused on the chemical rationalization of the processes described in the medieval text, gathering in-depth knowledge on the reaction mechanisms, which was essential in designing the experiments with which we could study the role played by each ingredient; the ingredients were either the main reactants or acted as catalysers or modulators.

During this first stage of research, the quantities used were significantly smaller than those in the medieval texts. In general, the processes reproduced may be divided into two categories: the production of inorganic compounds based in solid-state reactions using heat, and the production of dyes and lake pigments using methods based on solution chemistry and precipitation. For the solid-state chemistry, it will be necessary to assess the impact of having worked with quantities that were ten to one thousand times smaller than those described in the manuscripts. As future work, our next step will be to systematically compare the methods and quantities used in our manuscripts with other coeval treatises that also describe the production of these pigments.[11] We will also compile precise information concerning the sources of heat in use, as well as the most common types of furnace.

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[10] P. W. Atkins and L. Jones, *Chemistry: Molecules, Matter, and Change* (New York: W. H. Freeman and Co Ltd, 1997), 532.

[11] H. Lehmann-Haupt, *The Göttingen Model Book: A Facsimile Edition and Translations of a Fifteenth-Century Illuminators' Manual* (Columbia: University of Missouri Press, 1978); R. Córdoba de la Llave, "Un recetario técnico castellano del siglo XV: el manuscrito H490 de la Facultad de Medicina de Montpellier," *En la España Medieval* 28 (2005): 7–48; M. Clarke, *Mediaeval Painters' Materials and Techniques: The Montpellier Liber Diversarum Arcium* (London: Archetype Publications, 2011).

2. O livro de como se fazem as cores das tintas todas

The Book of All Colours describes the manufacture of colours used "to illuminate, paint and write"; the original text dates to the thirteenth century or earlier, and survives in a fifteenth-century copy (which was probably written in 1462 by Abraham ibn Hayyim).[12] These technical texts, written in Portuguese in Hebraic characters, were carefully preserved in the collection of texts Ms Parma 1959. The original manuscript, MS 1959, folios 1r-20r, is kept in Biblioteca Palatina, Parma (Italy). Its ultimate purpose was possibly to assist in the production of Hebrew Bibles, where the precision of the text would have been illuminated by the colours described in this *Book of All Colours*.[13]

The results of a recent study on *The Book of All Colours* – conducted by a multidisciplinary team led by Luís U. Afonso and Victor Serrão as part of a project called As Matérias da Imagem – were published in a homonymous monograph as well as in Débora Marques de Matos's dissertation and other publications by these authors.[14] Manuscript Ms. Parma 1959 has long attracted the attention of scholars; we should note especially the first edition in English by Blondheim (1928),[15] Moreira de Sá's Portuguese translation (1960)[16] and the more recent transliteration and English translation carried out by Devon Strolovitch in the context of his PhD thesis (2005 and 2010).[17] It is also important to mention an article by I. Villela-Petit,[18] who was one

[12] D. M. de Matos, *The Ms. Parma 1959 in the Context of the Portuguese Hebrew illumination* (Lisbon: Master's dissertation, Universidade de Lisboa, 2011), 116–17, and 175–6.

[13] Ibid., 178; T. Moita, *O livro hebraico português na Idade Média: do Sefer He-Aruk de Seia (1284–85) aos manuscritos iluminados tardo-medievais da Escola de Lisboa e os primeiros incunábulos* (Lisbon: Doctoral dissertation, 2016), http://hdl.handle.net/10451/28719.

[14] See, for instance, L. U. Afonso, "New Developments in the Study of O livro de como se fazem as cores das tintas," in *The Materials of the Image: As Matérias da Imagem*, ed. L. U. Afonso (Lisbon: Cátedra de Estudios Sefarditas "Alberto Benveniste" da Universidade de Lisboa, 2010), 3–27; I. Castro, "Notas sobre a língua do Livro de como se fazen as cores (ms. Parma 1959)," *The Materials of the Image: As Matérias da Imagem*, ed. L. U Afonso (Lisbon: Cátedra de Estudios Sefarditas "Alberto Benveniste" da Universidade de Lisboa, 2010), 87–96.

[15] S. Blondheim, "An Old Portuguese Work on Manuscript Illumination," *Jewish Quarterly Review* 19 (October 1928): 97–135.

[16] A. Moreira de Sá, "O livro de como se fazem as cores, de Abraao B. Judah Ibn Hayim," *Revista da Faculdade de Letras* 4 (1960): 210–23.

[17] Strolovitch, "O libro de komo se fazen as kores das tintas todas," 213–36.

[18] I. Villela-Petit, "Les Recettes pour l'enluminure du 'Livro' judéo-portugais de como se fazem as cores," *Medievalista online* 9 (2011).

of the first researchers to challenge the dating suggested by Blondheim. More recently, a new edition signed by Michel Larroche was also published.[19] Finally, our experimental edition of the "book of all colour paints,[20] based on Strolovitch's edition of the original Portuguese text, conveys the depth and clarity of the descriptions which are essential for the success of the processes outlined.

This paper discusses some relevant aspects of the technical processes involved, including an analysis of the tools used.

2.1. The colourants

The author described ten colours, but the list actually consists of eleven (illustrated in Fig. 1.1 below). Also, he only offers recipes for nine, as the process to produce *çufi* or lead white is not included. The process used to describe the production of blue (chapter five) does not result in a viable colourant. It should be added that the *çufi* colour is only mentioned in the list of "the ten main colours" (chapter twenty-seven), and for this reason the actual colour it refers to is uncertain. In his thesis, Devon Strolovitch suggests that the term is used as an adjective of carmine – a colour used by the "members of the Sufi sect of Islam."— This author suggests that the ten colour terms listed in the book do not correspond to common colour-denominations, but rather to their technical or commercial nomenclature: "these [principal colours] are not meant as the basic words of the language *per se*, but rather of the art or trade." Often, the treatise provides two variations of the same recipe, with the exception of vermillion and the watercolours iris green and *katasol* (see Fig. 1.2 below).

Azul	orpimento	vemelyon	verde	karmen	çufy
					
cap. 5	-	cap. 15	caps. 11, 12 & 45	caps. 13, 14	-

[19] M. Larroche (ed.), *Le livre des couleurs, O livro de como se fazem as cores (1462)* (Toulouse: PUM, 2017).

[20] Appendix in M. J. Melo et al., "The Book on How to Make all the Colour Paints for Illuminating Books: Unravelling a Portuguese Hebrew Illuminators," *Heritage Science* 6 (July 2018): 1–8; revised versions can be accessed online at www.dcr.fct.unl.pt/LivComoFazemCores.

katasol	açafrao	azªrkon	alvayª lde	brasil
				
cap. 24	cap. 36	cap. 10	-	caps. 8, 9, 27, 44

Fig. 1.1. “Ten are the main colours, blue, orpiment and vermillion, green, carmine, *çufi, katasol*, saffron, minium, lead white, brazil” (chapter twenty-seven).

	HgS	Pb_3O_4	SnS_2	Saffron*	Gum-varnish based carmine
Chapter	*15*	*10*	1 & 2	*36*	13 & 14

*Para obter amarelo de açafrão como tinta em iluminura

4 pinks	Noble blue	*katasol*	$Cu(CH_3COO)_2.H_2O$	Iris green
8, 9, 27 & 44	*5*	*24*	11 & 12	*45*

basta extrair com clara, ou seja, basta temperar

Fig. 1.2. Colourants and chapters in which their manufacture is described (for some colours, two – and in the case of pink, four – recipes are provided).

2.2. The four brazilwood-based recipes for pink and carmine

The lake pigments obtained from brazilwood are the only colourants with four recipes (see Figs. 1.1 and 1.2 above), including a translucent carmine (chapter forty-four), which would have been applied as a glaze, and three pink colours (dark opaque, bright, and very light) (see Fig. 1.3 below). Carmine, dark opaque pink, and bright pink were identified in a fifteenth-century book of hours, and the very light pink (chapter nine) is used in the *Ajuda Songbook*, which has been dated to the thirteenth century.

Lab* colour coordinates were used to describe carmine and differentiate between pinks, which were characterized by a lighter tone (higher L*) together with a component of yellow (b*>0) or blue (b*<0); all colours were characterized by a component in the red (a*>0). The analysis in Fig. 1.4 below shows that the red component a* appears most intensely in the pink described in chapter twenty-seven, followed in intensity by the pink described in chapter eight (both of which are urine-based recipes). The higher the quantity of calcium carbonate or gypsum present in the formula, the greater the opacity (higher L* value). The most opaque, and also lighter, pigments are those where white lead, a basic lead carbonate, or calcium carbonate (*pedra kri*) were added. Since both terms (*pedra kri* and *pau de giz*) feature in the technical lexicon of the treatise, we assume that, during that period as in today's Portuguese, *kri* and *giz* were used to designate "chalk" and "gypsum" (*cré* and *giz* in current Portuguese).

It should be noted that, of the two urine-based recipes, one presents a component of yellow and the other of blue (chapters eight and twenty-seven, respectively). The same is the case when we move on to the extraction of the colour in basic medium; one is characterized by a blue (chapter nine) and the other one by a yellow component (chapter forty-four). For the preparation of the alkaline media, an ash extract or lime water would have been used.

All recipes recommend scraping brazilwood very finely (*miúdo* or *muito bem*), except for that in chapter forty-four which recommends grinding it. In all recipes, the colourant is complexed with aluminium Al^{3+}, which is present in alum, and this would have resulted in an insoluble compound: a brazilwood lake pigment.[21] The ingenuous filtering process will be described in section 2.5 below, which deals with utensils.

[21] "'O livro de como se fazem as cores': Medieval Colours for Practitioners"; Vitorino, "New Insights into Brazilwood Lake Pigments Manufacture," 255–73.

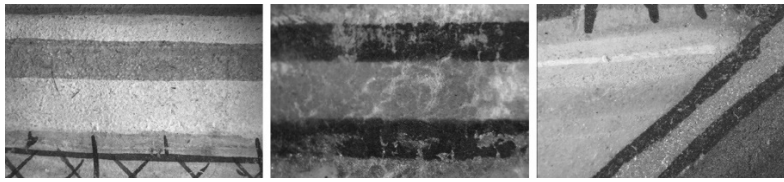

Fig. 1.3. From left to right, carmine colour in Book of Hours Ms 22, fl. 76 (x10); pink, Book of Hours Ms 24, fl. 60 (x50); pink, *Ajuda Songbook*, fl. 17 (x63). Source: Biblioteca do Palácio Nacional da Ajuda. Books of Hours from the Palácio Nacional de Mafra Collection.

	'title'	brazilwood	Al[3+]	additives	extraction	filtering	tempering	L* a* b*[§]
cap. 8	para fazer ros[a]h	brasil fino rapa-o meudo	pedra ume	alvaialde	urin[a]h (3 dias)	koa-o e apora-o por um pano de linyo e çima piah feit[a]h de gis o de pedra kri	kuando kiseires labrar ko.ele moio kon aguah gomada	47; 29; -0,3 48; 29; 5
cap. 9	para fazer otra ros[a]h	brasil ahrapa o been meudo	pedra ume	pedra kri	dekoad[a]k de vides (ao fogo e da-ly uah fervora)	-	fazer komo ga sabes de pedra ume ros[a]h	37; 18; -8 30; 15; -5
cap. 27	fazer boah ros[a]h	brasil rapa o muy ben	pedra ume	pao de giz	urina do omen kasto (3 dias)	pano alvo e koa-o sobre giß	moya kon krara dobo gomada	56; 39; -6 49; 38; -3
cap. 44	fazer boah roseta	brasil e mole-o no almofariß ke sega been moido peny[o]rao	pedra ume	-	kal virgen		destenpera kon goma	42; 18; 3 50; 21; 3,5

[§]pigments used on filter paper with a parchment glue, *1[a] linha*, (cap. 40) and gum water *2[a] linha*, (10% solution in gum Arabic).

Fig. 1.4. Ingredients and processes used to prepare brazilwood lake pigments in *The Book of All Colours*. For an English translation please see Strolovitch (2010), which can also be accessed at www.dcr.fct.unl.pt/LivComoFazemCores.

2.3. An incomplete recipe

Mark Clarke, in a critical edition of texts written in the fourteenth and fifteenth centuries, suggests that the term "tornasol" was used generically to designate a water-based colour stored in cloth ("clothlet").[22] Although the recipe conveyed in chapter twenty-four, which describes the preparation of *katasol*, is missing the beginning, we suggest that this "tornesol" is obtained from *Chrozophora tinctoria*. We base this hypothesis on the presence of the word "graos," grains/seeds, ("*panos o çumo de katasol e dos graos*"), and the fact that this species can be found in the Iberian Peninsula. The *Chrozophora tinctoria* is one of the plants used in the Middle Ages to produce watercolour "clothlets," which would fit in with the reference to grains/seeds ("graos"). These "graos" are found inside the small fruit (see Fig. 1.5), with the colouring dyestuff in its shell.

Along with the "noble blue" described in chapter five, this is one of the colours for which we cannot yet provide a molecular structure. In the case of "noble blue," a more thorough understanding of the raw material used, "*prata estena ben delgadas*" (thin sterling silver), is needed. Studies such as the one included in this volume – "Conception of the Quality of Copper: Some Sixteenth and Early Seventeenth-century Examples" – may provide new perspectives.

Fig.1.5. From left to right: *Chrozophora tinctoria*: detail of the fruits; cloth tinted with this fruit, according to the recipe conveyed in *The Book of All Colours*. That on the left has been exposed to urine vapour and that on the right has been exposed to the sun.

[22] M. Clarke, *The Crafte of Lymmyng and the Maner of Steynyng: Middle English Recipes for Painters, Stainers, Scribes, and Illuminators* (Oxford: The Early English Text Society, Oxford University Press, 2016), 44: 'turnesole, tornesole, tournesole, tursole; *n.* any colour of direct dye extracted from a flower or berry that is stored by being absorbed into a clothlet, to be subsequently released by immersion in a medium for e.g. an illuminator's colour, typically purple or blue (not a botanical name, i.e. not referring to the turnsole plants *Chrozophora tinctoria* (Juss.) or *Helotropium* spp., although the former plant itself may be used as the colour source)."

2.4. How to prepare colour paints for illumination

In addition to the colour components, pigment formulae must also include a binding medium, which allows the pigment to be used for painting. The tempering media used in *The Book of All Colours* are summarized in Fig. 1.6 below and include gum arabic or other gum solutions (*aguah gomada*), egg (both the white and the yolk were used), and a mixture of egg white and gum water. Only two of the references specify the use of gum arabic (the second recipe for mosaic gold and the one for noble blue). Most recipes (62%) recommend the use of polysaccharide binders, and many recommend the use of egg white (24%) and egg yolk (19%). For noble blue and *azul d'acre*, a mixture of gum and egg white is prescribed. It should be noted that recipes which recommend using gum are restricted to chapters twenty-eight to thirty-three – a section that deals with how pigments should be tempered, the mixture of colourants for shading and highlighting, and other details for illumination.

In addition to the main components, pigment and binders, other elements must be added to ensure the applicability and durability of the pigments, which are named "additives." Together, colourants, binders, and additives make a colour paint and its final aesthetic qualities and durability. These additives had various functions, such as improving the mechanical resistance of paint, increasing its adhesiveness and elasticity, and providing opacity. For instance, chalk (calcium carbonate) was frequently used to opacify brazilwood-based pink paints.

Fig. 1.6 (next page). Tempering media specified in the instructions in *The Book of All Colours*. For an English translation please see Strolovitch (2010), which can also be accessed at www.dcr.fct.unl.pt/LivComoFazemCores.

Colour	Chapter	Instructions
ouro musivo	1	kuando kiseires labrar ko.ele e destenpera-o ko aguah gomada
ouro musivo	2	kuando kiseres eskrever ko.el toma goma aravika koma un ervanço e o otro sega komo lentilya e deita aguah en uah vieira kontªh posa avondar agoma e kon ela destenpera o oro e eskerᵹbe
nobre azul	6	para tenperar o azul toma agoma arabika luzente e fina en aguah en uah taçªh e depois toma akela taçªh en.ke estuᵹber e koa-las kon o pano de linyo e toma a.terça parte da.krara do oᵹbo e deita ko.elªh no korno
azul d'acre*	7	pera tenperar o azul toma azul dakre e moyo ben ko.ah de koahda das vides levemente o kolyª o un uah veeyrah o konᵹgªh e lava-o kon akelªh de koadªh das vides e moy-o otrªh veß levemente kon uah pokªh de rosa e eskreve o ke kiseires o aluminªh o, pintªh o retªlyas uah pekenªh de krara dobo kon goma
Rosa	8	kuando kiseires labrar ko.ele moio kon aguah gomada
outro verdete (azinhafre; azinyabre)	12	pera ah des tenpraçon pera este verde kuando kiᵹseres labrar kou ele moyo ante mui bein e deitalyª e poko de açªfrao bein modo e destenpera-o kon aguah gomada
Catasol	24	kuando ko.ele kiᵹseres aluminar o labrar toma un korno been labado o uah vieyra e talya kon osos tesoyras un pekeno do pano do kª asol e deita-o na konᵹga o vieyra o korno e deita-lye da aguah gomadªh e depois keo pano for tomado ke seᵹgªh ben enbebidodela meçe-o bein e logo laᵹbraras kon.el
kein kiᵹser obrar kon oro o kon otras kores	25	*para a preparação da folha de ouro*: kon krara dob o ke seᵹgª muy fraka e muy liᵹgera
pera tenperar azul toma ah ᵹgema do obo	26	não é claro se a gema é usada como ligante, ou se é descrito um processo de purificação do azul
Catasol	26	detenpera o kon aguah gomada e en ton eskreᵹbe kon ele pero antes ke lyª deites aguah gomada seᵹga o azul been enᵹsuto da aguah e si kiᵹgeres podes deitar na ditªh krara do brasil por-lyª dar melyor kolor
boa rosa	27	toma esa rosa e moya kon krara dobo gomada
preparar clara de ovo	27	kuando kiᵹseres kebrar la krara do obo eᵹga alyª dela leᵹge dela figeira e kebralya as muito bein para tu obra klara komo aguah
Verdete	28	si kiᵹseres fazer verde e destenpera-o deita do vinagre kon do verde e da ᵹgema do obo e moyo todo de konson e as trespartes seᵹga h do verde e a kuartªh da ᵹgema e si o melyor kiᵹseres fazer deta-lyª da aguah gomada e destepªra-o kon ela
bom carmim	30	ᵹfilya o ka rmen aguah e da ᵹgema do obo kuanto ah metade e moy todo de konson e si kiᵹseres
Açafrão	31	si kiᵹseres destenperar açªfrao pera eskrever kon ele deitalye da krara do obo e nao o moyas
Ouropigmento	32	kon aguah e kon ᵹgema do oᵹbo e depois tira-o dinde esªh aguah e oᵹbra kon ele
Anil	33	destenperar o negro anil fila da aguah gomada o da ᵹgema de obo
mistura azul e carmim	37	meçkra todo kon da aguah gomada e kon da krara e podes perfilar e aluminar
cola de pergaminho	40	si kiᵹseres fazer kolªh toma dos pªrgaminos e lavª-os mui been e depois mete-os en uah olyª noᵹba e velya e faze-os e muito feber ata ke segªh been koᵹgos e deske for sumida ah primeira aguah mete dentro otra aguah e deske kiᵹgeres probar toma dela uah pokªh e pon-a ena pªlma e aᵹgunta uah mao kon otrªh e si prenderen as maos ten ke muy bein feitªh ah tªh kolªh
roseta	44	destenpera kon goma
verde do lírio	45	faze komo ao katªh sol nos vidos

*S. Kroustallis suggests this to be equivalent to indigo, whereas Afonso e Cruz suggest an equivalence with lapis lazuli.[1]

[1] Afonso, L. A., «New developments in the study of O livro de como se fazem as cores das tintas», Lisbon, 2010, p. 10.

2.5. Medieval tools and lab equipment

Fig. 1.7 presents the tools, equipment, and processes described in *The Book of All Colours*. In the processes are certain recurrent operations that include sifting, scraping, grinding, mixing, melting in the sense of dissolving, boiling, passing through a cloth or trough, smearing, and clarifying.[23] Many of these processes involve heating, which is referred to using the term *fogo* (fire) or the instruction "place on the fire"; in some recipes, the fire is described in some detail ("*fogo en suas fornalyas*"), but in most the reference is limited to the word "*fogo*." This information is complemented by a reference to the heat required in each step. The recipe for the preparation of mosaic gold provides a good example of the high level of detail that may be provided. The use of a furnace is mentioned for the first time in the second recipe for the preparation of mosaic gold (chapter two), and later for the production of minium (*azarcão*), where the text specifically prescribes the use of a "glass furnace." Concerning utensils, it should be noted that mortars, different containers, linen cloths and sticks feature in different recipes (especially interesting is the "*pau forcado*" described in chapter thirteen to produce lac dye). The word "*paleitah*" designates a scraping instrument, a kind of a knife or spatula, which would have been used to scrap the verdigris produced in chapter twelve, for instance. It would be interesting to examine the etymology of the words used to refer to the recipients: *bacio*, *panela*, *púcaro de barro*, *malga, taça*, *olha*, *alguidar*, *asado*. The description of the flasks (*redomas*) used in the first recipe (mosaic gold) and in the production of vermillion is also worthy of note. According to chapter one, glass flasks were used, which is an interesting detail since glass was relatively rare in the Middle Ages. The uses of glass and technology behind glassmaking during this period have been examined by Inês Coutinho.[24] The production of vermillion probably required a vessel like that described in the Sloane 73-0133v manuscript, a critical edition of which has recently been published by Mark Clarke, whom we thank for Fig. 1.8. a–b below.

[23] In Portuguese: peneirar, raspar, moer, misturar, mexer, derreter no sentido de dissolver, ferver, coar, untar, clarificar.

[24] I. Coutinho and M. Vilarigues, "The Use of Glass in Medieval Pigment Making," in *Proceedings of the 5th GLASSAC International Conference*, eds. I. Coutinho, T. Palomar, S. Coentro, A. Machado, and M. Vilarigues (Caparica: NOVA FCT Editorial, 2017), 19–21.

Fig. 1.7. Tools, equipment, and processes described in *The Book of All Colours*. For an English translation please see Strolovitch (2010), which can also be accessed at www.dcr.fct.unl.pt/LivComoFazemCores.

Chapters	Colour	Tools	Equipment	Processes	Binders
1	oro musiko	almofaris baçio **aredom^{a}h de vidro** panela	fogo	derreter misturar moer peneirar	destenpera-o (ko aguah gomada)
2	oro musiko	kulyar de fero grande pao (pau?) almofaris panela pano de linyo groso pokaro de baro tripees	forno	fonde-lo-as akalentar mesendo moer	goma aravika (koma un ervanço e o otro sega kono lentylia e deita aguah en uah vieira
5	nobre zul	p^{a}nela grande vergas de fero paleit^{a}h de palo o kan^{a}h		untar arapa-o	agoma arabika / terça parte krara do obo
8	ros^{a}h	taç^{a}h de male^{a}h pao (pau) pano de linyo paleit^{a}h	**pi^{a}h** feit^{a}h de giz o de pedra kri	rapa-o moy-o meçendo-os koa-o rapa-o	aguah gomada
9	otra ros^{a}h	olya	fogo	ahrapa fervora moy^{e} mistura	
10	az^{a}rkon		forno do vidrio	moyo peny^{a}ra	
11	azinhafre	olya / panel^{a}h		molyas soterah	
12	otro anizyabre	algidar baçio de laton p^{a}leit^{a}h		untado rapa	aç^{a}frao / aguah gomada
13	karmen	olya tigela pano e sako de linyo asado pao forkado fuste	fogo	kraros e eskumados fervao koar meçendo dereter	
14	otro karmen	olya pao sakos de linyo senyos testos ou tigelas		dereter (desolber) bolbe-o krarifikar koar sekar	
15	vermelyon	aredoma o tigel^{a}h vidrada pie de kao kon suah pele olyas feitas komo aredomas angas de guso e estreitasençima (= panelas) espeto delgado	fogo en suas fornalyas	meçendo moy-o enkorpora mistura	
24	katasol [falta frase abertura]	panos algidar bastoes		meçendo rebolbendo korados	toma un korno o uah vieira e talya kon tesoyras un pekeno pano do

					k^{a}tasol e deita-ly^{e} aguah gomad^{a}h
27	boa ros^{a}h	kong^{a}h o komo pano alvo	koa-o sobre gis	rapa moya	krara dobo gomada
31	aç^{a}frao				krara do obo e nao o moyas
44	boah roseta	almofaris		mole-o peny^{e}rao	destenpera kon goma
45	bou verde	panos dá o início depois remete para processo usado katasol		molya (molhar)	

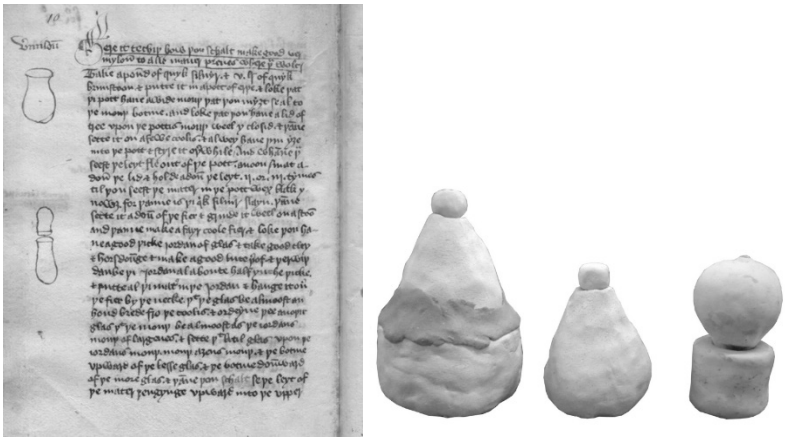

Fig. 1.8. a–b. Vessels used for the production of vermillion, described in chapter fifteen, might have been similar to those suggested in the manuscript Ms Sloane 7, f. 133v. To the right are some of the examples prepared by the students of the master's in conservation and restoration (UNL).

2.6. Precise instructions and essential information

We consider the following set of instructions exceptional due to their usefulness: (i) the use of a dog leg (fur included) when mixing sulfur and mercury, the first step in the production of vermillion; (ii) the chalk or gypsum stones used for filtering in those recipes that use brazilwood, in chapters eight and twenty-seven (the use of which is described in particular detail in chapter eight: "*pia feita de giz ou de pedra crê*"). Our proposal concerning the use of gypsum vessels is illustrated in Fig. 1.9. a–b below,

where it is compared with a diagram from Ms Sloane 964 (kindly provided by Mark Clarke).[25]

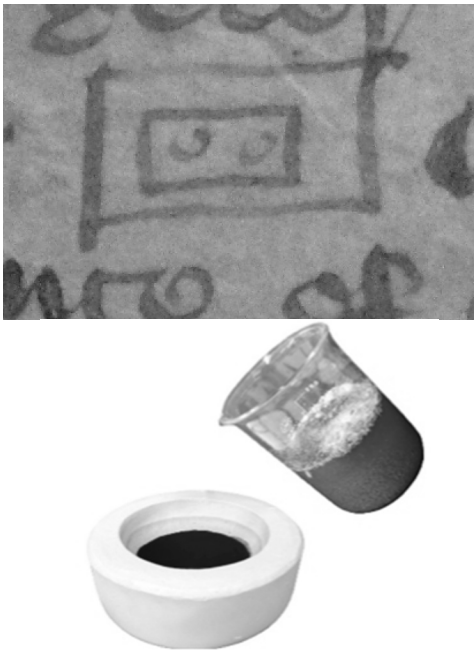

Fig. 1.9. a–b. Bottom, our recreation of the gypsum-stone described in chapter eight for the production of brazilwood lake pigments. In contrast with the chalk-stone described in Ms Sloane 964, f. 62r, ours does not have holes in the bottom.

The reference to the use of a "*pé de cão com a sua pele*" in the production of vermillion is particularly valuable because it conveys the difficulties of working with mercury. Dog leg and gypsum/chalk-stone are therefore essential tools in the production of certain colours. The use of "*pia*" speeds up the filtering process, and when scraping it can also introduce the filler (gypsum or chalk) which provides the necessary opacity. Our "*pia*," in contrast to that illustrated in Fig. 1.9. a–b above, does not have holes; in our case, they were not considered necessary because the quantities we were using were much smaller than those prescribed in the original recipe.

[25] Clarke, *The Crafte of Lymmyng,* 306.

3. Conclusions and Future Perspectives

The experiments carried out over the past ten years have allowed us to gain an in-depth knowledge of the processes described in Ms Parma 1959, whose *incipit* begins with the expression "*aki se.komeinça o libro de komo se fazen as kores das tintas*."

We believe that our studies sufficiently demonstrate that most of the colours described can be obtained in the laboratory by following the steps prescribed in the recipes. In the conclusion to her dissertation, Débora Marques de Matos suggests that the colours described in *The Book of All Colours* could have been used to illuminate Portuguese Hebraic manuscripts.[26] For this reason, we posit that this is a treatise about how to produce artificial colours and paints for the illumination of the sacred book. We also suggest that the text was divided into three parts. Our division differs somewhat from that proposed by Luís U. Afonso and Débora Marques de Matos.[27] As such, the first part includes the basic description of how to produce the colourants (chapters one to fifteen); the second part deals with miscellaneous procedures, including dyeing wood and bone and the gilding of a sword; the one page missing in the production of blue/tornasol purple (*katasol*) makes its contextualization uncertain (chapter twenty-four); the third part (chapters twenty-five to forty-four) describes the production of the colour paints, including instructions for producing binders, mixing colours and painting, as well as concocting a varnish which, in our opinion, was not used in illuminated manuscripts. The recipes for producing *katasol* and iris green (*verde de lírio*) (chapter forty-five) seem somehow out of place. They mention a type of colourant, anthocyanin, that has not yet been detected in medieval illuminated manuscripts to date. The absence of a recipe for the production of writing ink is also surprising and it can be speculated that such a recipe may have been on the missing page.

As future research, taking into consideration Tiago Moita's PhD thesis on the study Portuguese medieval Hebraic manuscripts (codicological and art history perspectives),[28] we suggest that the molecular analysis of the colours used in these manuscripts, starting with those dated to the fourteenth and fifteenth centuries, will provide a significant contribution to our

[26] Matos, *The Ms. Parma 1959*, 179.
[27] Afonso, "New Developments in the Study of O livro de como se fazem as cores das tintas," 1–15, 16–24, 25–45; Matos, *The Ms. Parma 1959 in the Context of the Portuguese Hebrew Illumination*, part 1: 1–16, part 2 (dyeing bone and wood): 17 – 22/23, part 3 (colour tempering; also colour shades and variations): 24–40, part 4 (several subjects): 41–5.
[28] Moita, *O livro hebraico português na Idade Média*.

understanding of these manuscripts. It would also be fruitful to compare the colourants based on *The Book of All Colours* with those described in other Iberian sources, such as the Ms H490 manuscript in Montpelier, edited by Ricardo Córdoba de la Llave.[29]

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[29] Córdoba de la Llave, "Un recetario técnico castellano del siglo XV," 7–48.

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