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ORIGINAL PAPER

First experimental evidence of hop fibres in historical textiles

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Abstract

Hop (*Humulus lupulus*) has been used in Scandinavia since at least the ninth century AD, as documented through archaeological findings and written, historical records. The written records are mainly focused on the use of cone-shaped flowers for beer brewing and medical purposes, but there are also records, for example, from the famous Swedish botanist Carl von Linne, who mentions the use of hop fibres for textile production. However, until now no experimental investigations have been published on the use of hop fibres in cultural heritage objects. A major reason for this has been the lack of a suitable characterization method. Hop is a bast fibre, just as flax and hemp and bast fibres cannot be distinguished from each other by simple optical inspection. Recently a new identification method for hop fibres was published by the authors of this article. Here we apply the new method in an investigation of two Swedish cultural heritage objects: (i) a woman's garment from the nineteenth century, which was labelled as having an upper section made from coarse linen and a bottom section made of hemp and hop and (ii) a textile fragment from an eighteenth-century textile sample book, which was labelled as being made from hop. We show that the woman's garment is made with hop and hemp fibres and the textile fragment from the textile sample book is made with hop. Our work provides the first direct proof that hop fibres were used for textiles in the past.

Keywords Fibre identification · Hop · *Humulus lupulus* · Historical textiles · Herzog test · Cuoxam

Introduction

Hop (*Humulus lupulus*) is an ancient perennial crop plant, native to the Northern hemisphere. The oldest cultivated archaeological findings from Scandinavia, where it is clear that the findings are hop, are macrofossils from Birka, dating back to the ninth century AD (Hansson 1996, 129). Hop is frequently mentioned in historical, written records. The main emphasis is on the use of hop flowers for beer brewing, but other applications are also mentioned: hop flowers were applied for medical purposes (i.e. sleeping draughts) and for embalming and placed in burial coffins, for example, as filling in pillow cases (Strese and Tollin 2015, 263–273).

One of the oldest parts of the Frostathing law (*Frostatingsloven*), coming from the twelfth century, mentions cultivation of hop Book XIII, no. 11 (Hagland and Sandnes 1994, 93). In the Middle Ages in Norway, it was a duty for all farm owners to cultivate a certain amount of hop plants (Høeg 1976, 385). The same was the case in Sweden, where hop growing was obligatory from 1414 until 1860 (Karlsson Strese et al. 2014). On the other hand, records of cases of restrictions, where hop production was forbidden within certain areas and time periods, can also be found (Lankester 1840, 68).

It is documented through written records that hop fibres extracted from the plant stem were used for textile production in Scandinavia from around 1600 up to the nineteenth century (Bromelio 1687, 66–67; Schissler 1750, 214–216; Hald 1980, 130; Strese and Tollin 2015, 255–256). Carl von Linne mentions in his *Flora oeconomica* the use of hop for textile production. He writes that if the hop stalks are retted, they can be used for yarn similar to hemp (Linné and Aspelin 1749, 60–61). In 1773, the Norwegian topographer Gerald Shoning describes a travel to Surnadal (Norway). He mentions that in 1758, hemp, hop and also linen goods were imported to Trondheim (Schøning 1778, 10). He also states that flax, wool, hemp and hop were used to make fabrics (Schøning

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1778, 20). In 1781, Fischerström (1781) comments that hop stalks are normally thrown away but that one ought to do as in Jamtland and Medelpad, where they are used to make a weave, which is stronger than flax and hemp. (Fischerström 1781, 486). A fairly recent source mentions that hop fibre quality can vary a lot (Tobler 1938, 84–87). Experiments with substitute materials for textiles were also referred by Freund (1972, 7).

The most widely used textile plants in Scandinavia until the beginning of the twentieth century were flax (*Linum usitatissimum*) and hemp (*Cannabis sativa*). Hemp was used for cordage and coarse textiles, but there are also examples of the use of hemp for finer fabrics (Skoglund et al. 2013; Skoglund 2016). A few cases are documented, where stinging nettle (*Urtica dioica*) has been used for textile production (Hald 1942, 29–49; Bergfjord et al. 2012). Hop fibres were most likely not a very commonly used material compared with other textile materials.

Flax, nettle, hemp and hop are all bast fibres and it is not possible to distinguish them by simple optical inspection (Bergfjord and Holst 2010; Bergfjord et al. 2010; Haugan and Holst 2014). This may well have led to some textiles being incorrectly labelled as made of flax in various museum collections. It should also be noted that during the eighteenth century in Scandinavia, the term *linne* (Swedish) and *lin* (Norwegian) became common as a term to describe a plain weave textile irrespective of what it was made of. Earlier, a plain weave textile was often referred to as *lærred or lärft* in Swedish (Geijer 1979, 17). The terms *linne and lin* are however also used specifically for textiles made from flax. The modern word for flax is *lin* in both Swedish and Norwegian. The difficulties in terminology concerning linen also apply to the German *Leinwand* (Küster-Heise and Mitschke 2011, 159).

In order to find out what plants have been used to produce historical textiles, systematic investigations of objects in cultural heritage collections using the appropriate identification methods are necessary (see, e.g. Lukešová et al. 2017). Precise knowledge of material use in cultural heritage collections is important because it will enable better understanding of resource management in the past.

In this article, we present the first investigation on cultural heritage objects performed with the specific aim of finding out if they are made of hop; we use a very recently developed identification method (Lukešová et al. 2019).

The samples investigated

We investigate two historical objects in this article: the first object is a woman's garment from Jamtland County in Sweden (NM.0131474, left), belonging to the Nordic Museum in Stockholm (Fig. 1). It was donated to the museum in 1917. According to the museum accession record, the donor stated that the upper section is made of coarse linen fabric and the bottom section of hemp and hop (Redogörelse för Nordiska museets utveckling och förvaltning år 1919, p.11). The garment was probably produced in the middle of the nineteenth century. It is written in accession record that it was around 65 years old when it was donated to the Nordic Museum (https://digitaltmuseum.se/011023635901/overdelssark, downloaded 28.4.2020).

The upper section is made of twill fabric, which is rather greyish and soft in its appearance compared with the bottom section which is made of coarse tabby with a yellow tinge. The object is described in Skoglund (2016). It is stated here that a Herzog test fibre analysis suggests an upper section made with a mixture of flax and hemp and/or hop and a bottom section made with hemp and/or hop. No further details to the analysis are presented (i.e. regarding thickness of the fibres investigated).

The second object is a textile fragment glued onto a sheet of paper in a Swedish textile sample book (NM.0405398+) from 1766 (Fig. 1, right). The book presents a sample collection of textiles produced in the eighteenth century. The purpose of assembling the collection was to inspire an increase in Swedish textile production.

Methods, including sample preparation

Samples of both objects—the woman's garment from Jamtland and the textile fragment from the textile sample book—were carefully extracted and investigated by white light transmission and polarized light microscopy. In addition, microchemical tests using cuoxam-tetraamminediaquacopper dihydroxide $[Cu(NH_3)_4(H_2O)_2](OH)_2$ were performed at the end of investigation, in order to investigate the swelling behaviour (Luniak 1953, 80; Wülfert 1999, 281–282, 320; Stratmann 1973, 58–62). The investigations were performed following the recently developed identification method for hop fibres (Lukešová et al. 2019). See also Fig. 2.

For the Jamtland garment, four core samples were extracted since it was made of two different fabrics: two samples of the weft and warp system from the upper section (samples 1 and 2) and two samples of the weft and warp system from the bottom section (samples 3 and 4). For the textile fragment from the textile sample book, we only sampled the thread system of the shorter side (sample 5); it is so small. Both thread systems (warp and weft) show similar thread thickness, spin direction and colour when observed by stereomicroscope. We carefully evaluated ethical issues when sampling and concluded we perform the tests on one thread system only.

Five sub-samples (consisting of single fibres) were made from each core sample. Two of them were mounted in Meltmount (n_D = 1662) (labelled samples 1.1, 1.2, 2.1, 2.2,

Fig.1 (Left) The female upper garment from Jamtland county in Sweden (NM.0131474), 89 × 130 cm; (right) the fabric sample in a Swedish fabric sample book from 1766 (NM.0405398+), the lower sample was investigated (© The Nordic Museum in Stockholm)

3.1, 3.2, 4.1, 4.2, 5.1 and 5.2). The three remaining sub-samples from each core sample were mounted in distilled water according to an established protocol (Wülfert 1999, 325). These sub-samples (labelled sample 1.3, 1.4, 1.5, 2.3, 2.4, 2.5, 3.3, 3.4, 3.5, 4.3, 4.4, 4.5, 5.3, 5.4 and 5.5) were subsequently used for microchemical tests in cuoxam. Sample preparation was done using a stereomicroscope to be able to separate fibre bundles. Very fine tweezers and tungsten needles were used when manipulating single fibres; for a detailed description of fibre sample handling and mounting, see Lukešová (2018).

The samples were investigated using a polarized light microscope Leica DM750 P. A full wave compensator (λ = 530 nm) was used for the modified Herzog test (Herzog 1922, 1943; Haugan and Holst 2013). Photographs were taken using the camera Leica MC170 HD and software LAS V4,9. Fibres

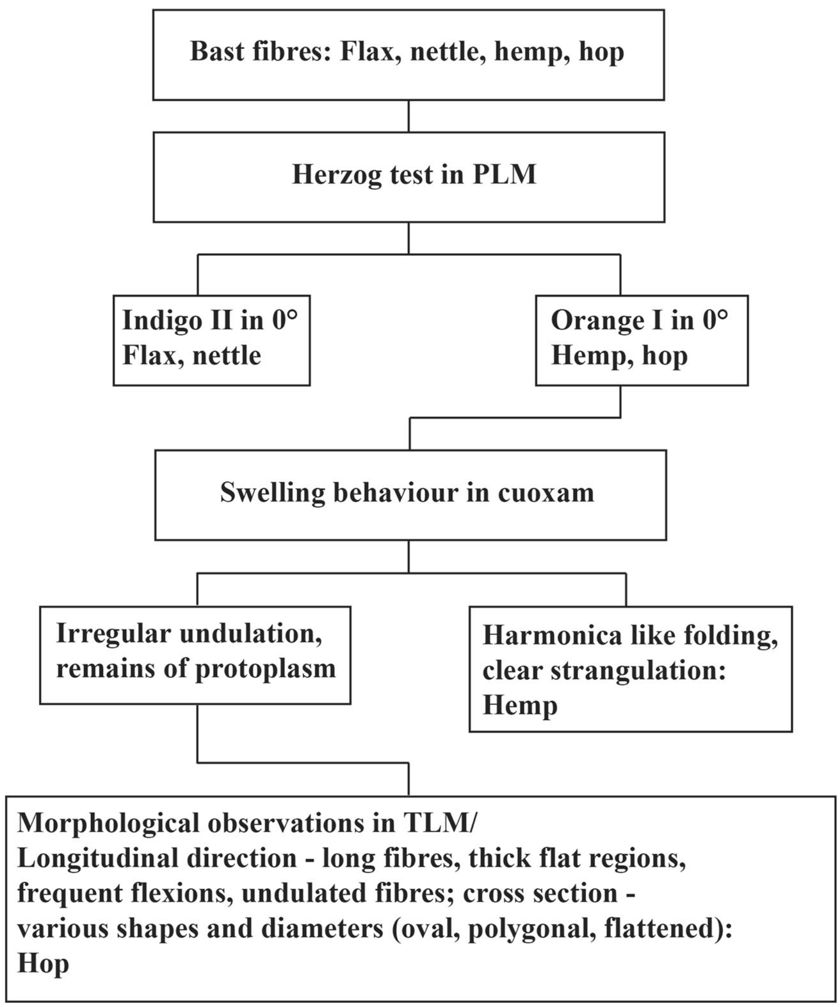

Fig. 2 Diagram for identification of hop fibres, reproduced from Lukešová et al. (2019), Herzog test, modified Herzog test; PLM, polarized light microscopy; TLM, transmission light microscopy

were first observed in transmitted white light. Polarized light was used for performing the modified Herzog test. Fibres thinner than 20 μm were not used for the Herzog test since an experience with reference samples has shown that they may give misleading results. A demonstration video on how to perform the Herzog test can be found on https://youtu.be/sC9GlUKjBDE.

Results

We followed the diagram elaborated for the identification of hop fibres shown in Fig. 2.

Polarization microscopy and the modified Herzog test

All samples except sample 1.5, which had no suitable region for testing, show Orange I in 0° and Indigo II in 90° position according to Michel-Levy birefringence chart when performing the modified Herzog test (Fig. 3).

Numerous crystals, probably calcium oxalates or other phytoliths, were clearly visible in all sub-samples except sample 1.4 (this is not used as an identification criterion).

Microchemical tests using cuoxam

Cuoxam, also called Schweizer's reagent, is an established tool for fibre identification since it causes swelling typical for species. All tested sub-samples show irregular undulation when swelled in cuoxam (Fig. 4, upper left and right) which together with the Herzog test result indicates hop. Samples 3.5; 4.3 and 4.4 show in addition harmonica-like folding of the middle lamella on some fibres, which indicates hemp (Fig. 4, lower left and right).

All sub-samples except 3.5 show clearly visible remains of protoplasm in the lumen. Sub-samples 1.3; 1.5; 2.4; 3.4; 4.3 and 5.4 showed a typical rounded edge of a fibre with a plasma thread sticking out (Fig. 4, upper right).

White light microscopy

All samples show strong, irregular thickness variations along the fibre lengths. This is one of the most characteristic features for hop (Fig. 5, lower left). There are wide flattened regions without cross marks that are even and smooth (Fig. 5, upper left and right). These often alternate with regions containing frequent cross marks and dislocations. All original samples show frequent flexions (Fig. 5, lower right). Undulated fibres (many twist flexion after each other) that might remind one of cotton fibres are also common.

We conclude that the upper section of the woman's garment NM.0131474 is made with hop (*Humulus lupulus*) and the bottom part is made with a fibre blend of hop and hemp (*Humulus lupulus* and *Cannabis sativa*). The textile fragment from the textile sample book (NM.0405398+) is made with hop (*Humulus lupulus*)—only one of the thread systems was investigated, because of the limited amount of original material.

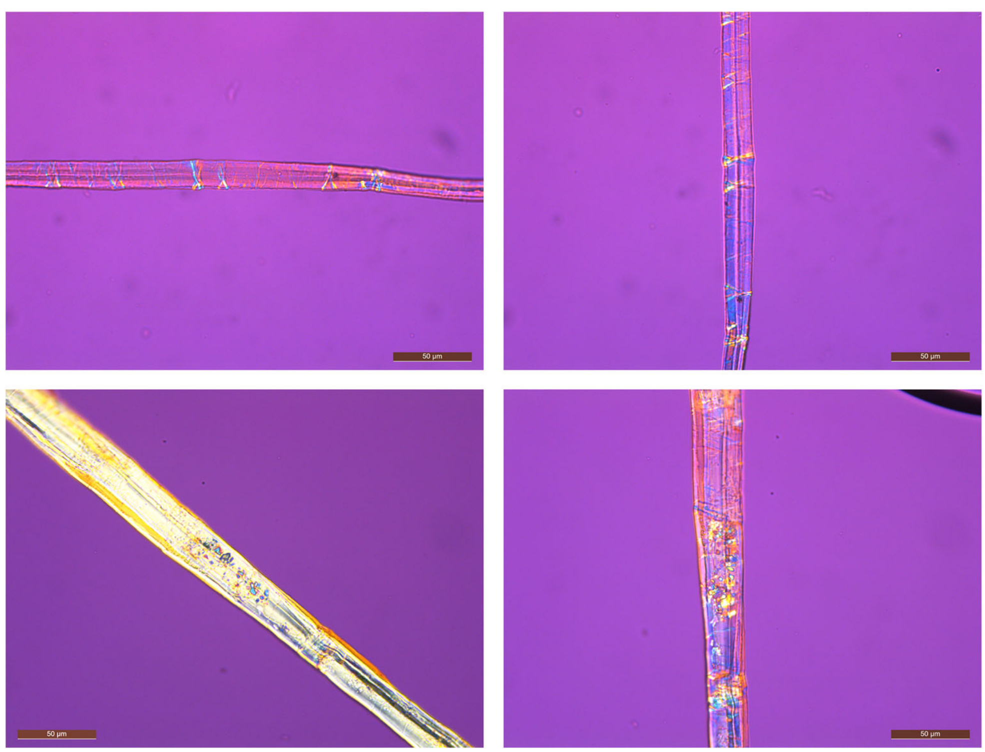

Fig. 3 (Upper left and upper right) Sample 1.2 showing Orange I in 0° and Indigo II in 90° position; (lower left and lower right) sample 3.1 showing numerous small crystals, probably calcium oxalates or other phytoliths, which are visible as small areas with pronounced, strongly varying interference colours (the objective HI PLAN POL × 40/0,65 used for all four figures)

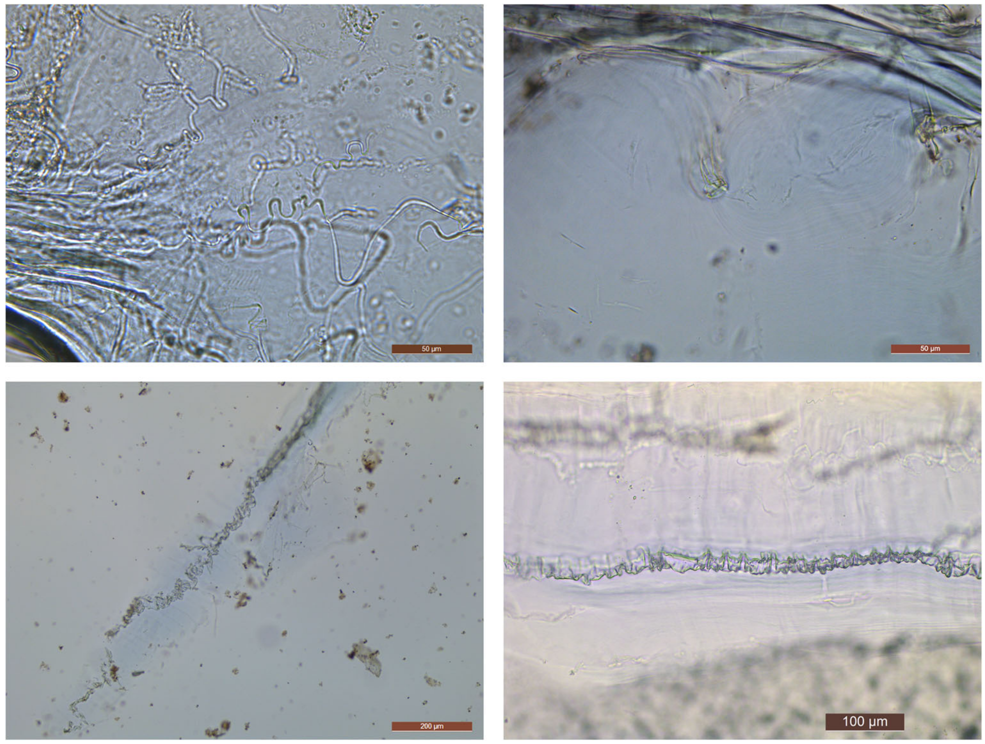

Fig. 4 (Upper left) Sample 4.3 in cuoxam showing ribbon-like pattern typical for hop fibres; (upper right) sample 1.3 showing plasma thread sticking out of rounded edge of a fibre, which is typical for hop fibres (the objective HI PLAN POL × 40/0,65 used for both figures). (Lower left) Sample 4.3 showing harmonica-like folding of cell wall in cuoxam typical for hemp (the objective HI PLAN POL × 10/0,25 used); (lower right) hemp reference fibre: typical harmonica-like folding in cuoxam (the objective HI PLAN POL × 20/0,40 used)

Discussion

We have conducted a fibre identification analysis of two historical objects: a woman's garment (NM.0131474) and a textile fragment from a textile sample book (NM.0405398+). Based on the behaviour of fibre samples from the two objects in polarized light, characteristic swelling in cuoxam and distinctive fibre morphology using the identification method (Lukešová et al. 2019), we conclude that for the garment NM.0131474, the upper part is made with hop fibres and the

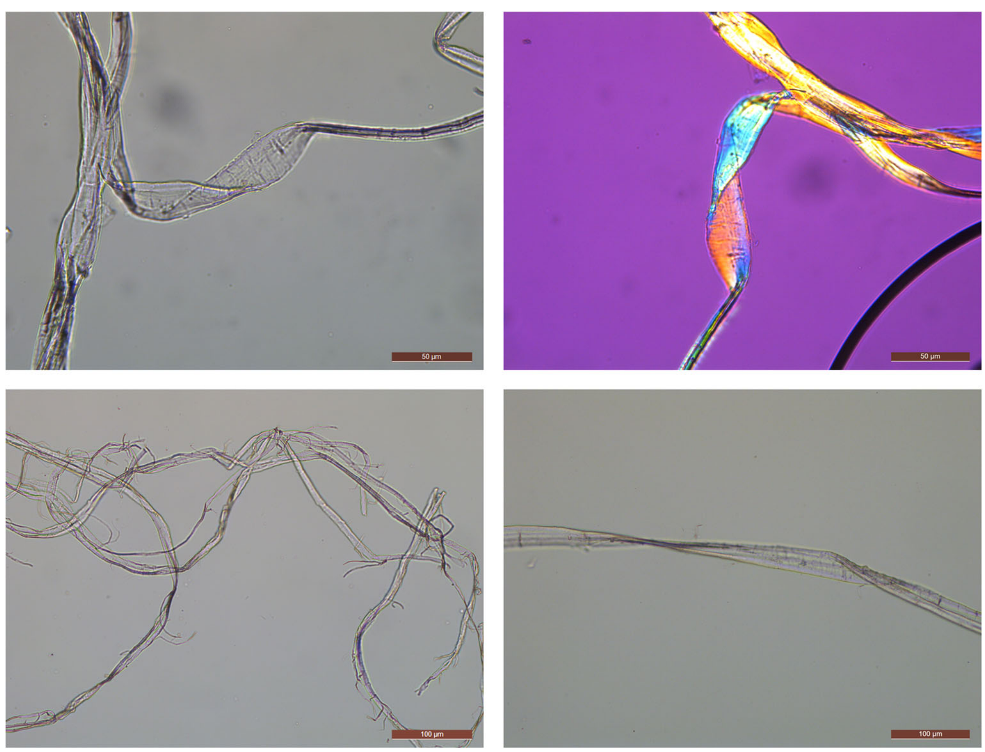

Fig. 5 Sample 1.1. (Upper left) Wide, flattened regions without cross marks are typical for hop fibres; (upper right) the same micrograph in crossed polars, with full wave compensator inserted. These flattened regions often show strong interference colours (the objective HI PLAN POL × 40/0,65 used for both figures). (Lower left) Thickness variations along the fibre's length in an irregular way; (lower right) twists typical for hop fibres (the objective HI PLAN POL × 20/0,40 used for both figures)

bottom section is made with a fibre blend of hop and hemp fibres. The quality of the upper section is rather soft and fine compared with the bottom section. This shows that the textile quality is a result of fibre processing and selection and is not an inherent quality of the plant fibre species used.

Our fibre analysis result for the upper section differs from that of Skoglund (2016, p. 88), who claims that flax is also present. Of course, we cannot exclude that sampling on two different sections of the garment may contain different fibres. Alternatively, if very thin fibres (less than 20 μm diameter) were investigated, a false result is possible as investigation on reference samples have shown. It is important to take into consideration that methods in microscopy, such as fibre analysis and microchemical tests, are comparative studies that build upon each other. Note also that the identification method used here (Lukešová et al. 2019) is for cultivated hop (*Humulus lupulus*). Wild hop has not been investigated. It is very probable that the objects investigated here are made of cultivated hop, but we cannot exclude wild hop completely.

We note that the original museum accession record states that the upper section is made of coarse linen and the bottom section of hemp and hop. Strictly spoken this is not wrong, since linen just refers to the weave, but as mentioned in the introduction, linen is often taken to mean flax, and when other types of fibres are explicitly mentioned, flax is the natural association. Another recent report states that the upper section is made of hemp (Frankow 1992, p.75), which is incorrect. The fabric sample from the textile sample book (NM.0405398+) is made with hop fibres. This agrees with the information in the textile sample book.

Conclusion

In this paper, we present the first experimental evidence of hop fibres in historical textiles. The fibre identification is based on the behaviour of fibres in polarized light, characteristic swelling in cuoxam and fibre morphology following (Lukešová et al. 2019). Both objects are investigated: the woman's garment (NM.0131474) and the textile fragment from the textile sample book (NM.0405398+) confirm the use of hop fibres. Our results highlight the importance of careful material analysis of cultural objects. Precise knowledge of material use in cultural heritage collections is crucial because it is necessary for understanding resource management in the past.

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References

Bergfjord C, Holst B (2010) A procedure for identifying textile bast fibres using microscopy: flax, nettle/ramie, hemp and jute. Ultramicroscopy 110:1192–1197. https://doi.org/10.1016/j.ultramic.2010.04.014

Bergfjord C et al (2010) Comment on "30.000-Year-Old Wild Flax Fibers". Science 328:1634

Bergfjord C et al (2012) Nettle as a distinct Bronze Age textile plant. Scientific Reports 2:664. https://doi.org/10.1038/srep00664

Bromelio O (1687) Lupulogia, eller en liten Tractat den gemene Ländtmannen fast nyttyg och nödig

Fischerström J (1781) Nya swenska economiska dictionnairen. Eller försök til et almänt och fullständigt lexicon, i swenska hushållningen och naturläran. 1-4. 1779-92. Del 3. Tredje delen. Tryckt i Kumblinska tryckeriet. Stockholm

Frankow I (1992) *Hampa eller inte?* Nordiska Museet och forfattarna, Bohusläningens Boktryckeri AB, Uddevalla

Freund H (1972) Geschichte der Mikroskopie der technisch verwendeten natürlichen und synthetischen Faserstoffe, *Handbuch der Mikroskopie in der Technik*, VI(1). Frankfurt

Geijer A (1979) A history of textile art. London

Hagland JR, Sandnes J (1994) *Frostatingslova.* Norrøne bokverk. Det norske Samlaget. Oslo

Hald M (1942) The nettle as a culture plant. In: *Folkliv : tidskrift för nordisk etnologi. Journal for Nordic and European ethnological researc*. Bokförlags A.-B. Thule. Copenhagen

Hald M (1980) Ancient Danish textiles from bogs and burials: a comparative study of costume and Iron Age textiles. *Olddanske tekstiler*. Copenhagen. *Serie:* Nationalmuseets skrifter. Arkæologisk-historisk række. Copenhagen

Hansson A-M (1996) Finds of hops, *Humulus lupulus* L., in the black earth of Birka, Sweden, in *Arkeologiske Rapporter 1*, Esbjerg Museum, 129–137

Haugan E, Holst B (2013) Determining the fibrillar orientation of bast fibres with polarized light microscopy: the modified Herzog test (red plate test) explained. Journal of Microscopy 252(2):159–168. https://doi.org/10.1111/jmi.12079

Haugan E, Holst B (2014) Flax look-alikes: pitfalls of ancient plant fibre identification. Archaeometry 56(6):951. https://doi.org/10.1111/arcm.12054

Herzog A (1922) Zur Unterscheidung von Flachs und Hanf auf optischem Wege. Textile Forschung 4:58–61

Herzog A (1943) Polarisationsbilder der Faserstoffe in Natürlichen Farben. *Klepzigs Textil-Zeitschrift* 13(14):171–177

Høeg OA (1976) *Planter og tradisjon. Floraen i levende tale og tradisjon I Norge 1925-1973*. Universitetsforlaget, Oslo

Karlsson Strese EM et al (2014) Genetic diversity in remnant Swedish hop (*Humulus lupulus L.*) Yards from the 15th to 18th Century. *Economic Botany* 68(3):231–245

Küster-Heise K, Mitschke S (2011), Textilterminologie in der Museumsarbeit unter besonderer Berücksichtigung der Textilterminologie, Information. Wissenschaft & Praxis, 60: 159

Lankester E (1840) *Vegetable substances used for the food of man - materials of manufacture*. London

Linné C, Aspelin E (1749) *Flora oeconomica, eller Hushållsnyttan af de i Swerige wildt wäxande örter = Flora oeconomica or Household uses of wild plants in Sweden* 18, Suecica rediviva. Facsimile 1971. Stockholm

Lukešová H (2018) Application of the Herzog test to archaeological plant fibre textiles. The possibilities and limits of polarised light microscopy, In: *Archaeological Textiles – Links Between Past and Present*, (eds. Bravermanová, M., Březinová, H. Malcolm-Davies, J.), conference proceedings NESAT XIII, Liberec - Praha

Lukešová H, Palau AS, Holst B (2017) Identifying plant fibre textiles from Norwegian Merovingian Period and Viking Age graves: the Late Iron Age collection of the University Museum of Bergen. *Journal of Archaeological Science: Reports* 13:281–285. https://doi.org/10.1016/j.jasrep.2017.03.051

Lukešová H, Andersen HL, Kolínová M, Holst B (2019) Is it hop? Identifying hop fibres in a European historical context. *Archaeometry* 61(2):494–505. https://doi.org/10.1111/arcm.12437

Luniak B (1953) *The identification of textile fibres: qualitative and quantitative analysis of fibre blends*. Sir Isaac Pitman and Sons, Ltd., London

Redogörelse för Nordiska Museets utveckling och förvaltning år 1917. Stockholm. Kungl. Boktryckeriet. P.A. Norstedt & Sönder. (1919) http://runeberg.org/fataburen/1917r/0003.html

Schissler PH (1750) Försök, huru man af Humble-tågor kan få linbast. In: Kungl. Svenska vetenskapsacademiens handlingar, Stockholm, 214-216. http://hosting.devo.se/kvah/catview.html?method=start&bookId=714&articleId=19803&skipSearchCriteria=false. Accessed 22 Jan 2020

Schøning G (1778) Reise som giennem en deel af Norge i de aar 1773. Bd 1. Trondhjem. https://www.nb.no/items/URN:NBN:no-nb_digibok_2010031212001?page=23. Accessed 22 Jan 2020

Skoglund G (2016) *Hampa: det vita guldet - textilväxten Cannabis Sativa*, Gidlunds förlag

Skoglund G, Nockert M, Holst B (2013) Viking and Early Middle Ages northern Scandinavian textiles proven to be made with hemp. Nature Scientific Reports 3:2686. https://doi.org/10.1038/srep02686

Stratmann M (1973) *Erkennen und Identifizieren der Faserstoffe*, Dr.-Ing. Oskar Spohr-Verlag, Stuttgart

Strese EM, Tollin C (2015) Humle. Det gröna guldet. Nordiska Museets Förlag

Tobler F (1938) Deutsche Faserpflanzen und Pflanzenfasern. Lehmann, München

Wülfert S (1999) *Der Blick ins Bild. Lichtmikroskopische Methoden zur Untersuchung von Bildaufbau, Fasern und Pigmenten*. Ravensburger Buchverlag, Ravensburg