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Reporting Summary

Nature Research wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Research policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a	Confirmed	
☐	☒	The exact sample size (*n*) for each experimental group/condition, given as a discrete number and unit of measurement
☐	☒	A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly
☐	☒	The statistical test(s) used AND whether they are one- or two-sided *Only common tests should be described solely by name; describe more complex techniques in the Methods section.*
☐	☒	A description of all covariates tested
☐	☒	A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons
☐	☒	A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)
☐	☒	For null hypothesis testing, the test statistic (e.g. *F*, *t*, *r*) with confidence intervals, effect sizes, degrees of freedom and *P* value noted *Give P values as exact values whenever suitable.*
☒	☐	For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings
☒	☐	For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes
☒	☐	Estimates of effect sizes (e.g. Cohen's *d*, Pearson's *r*), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection	AFM: NanoScope 9.2 (Bruker); Nanoindentation: NanoSuite 5.0 (Agilent Technologies); FTIR-ATR: OPUS 6.5 (Bruker); SHG: NIS-Elements 4.20 (Nikon). XRD: Datascan 4.0 NMR: Topspin 3.5 (Bruker) Nanotomography: Xact 64 from RX Solution withVoxel size 0.58µm, Tube Voltage 50kV, Tube current 101µA, 0.25 image/s
Data analysis	AFM: Gwyddion 2.52 (Opensource from department of Nanometrology, Czech Metrology Institute, Czech Republic http://gwyddion.net/), SigmaPlot 11.0 (Systat Software Inc); Nanoindentation: Microsoft Office Excel 16.38; FTIR-ATR: OPUS 7.5 (Bruker) , SigmaPlot 11.0 (Systat Software Inc); SHG: NIS-Elements Viewer 4.50 (Nikon). XRD: Microsoft Office Excel 16.38; NMR: Peakfit 4.11 Nanotomography: VG StudioMax 3.4 from Volume Graphics GmbH, Germany.

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

The authors declare that most data supporting the findings of this study are available within the paper and its supplementary information files. All other data supporting the findings of this study are available from the corresponding author upon reasonable request.

Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

☐ Life sciences ☐ Behavioural & social sciences ☒ Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Ecological, evolutionary & environmental sciences study design

All studies must disclose on these points even when the disclosure is negative.

Study description	The study focuses on the morphological, ultrastructural and mechanical characteristics of a yarn from an Egyptian mortuary linen, dating from the early Middle Kingdom (Eleventh dynasty, ca. 2033 - 1963 BCE), using advanced microscopy techniques, such as nano-tomography, multiphoton excitation microscopy and atomic force microscopy, and compared against a modern flax yarn.
Research sample	Two samples of flax (Linum usitatissimum L.) yarns were studied, an ancient and a contemporary sample: i) A piece of yarn about one cm long was taken from the edge of a old Egyptian linen tabby; ii) In addition, a contemporary flax yarn was used; it was produced from textile flax (Linum usitatissimum L., Melina variety) cultivated in 2018 in Normandy (France) by Teillage Saint-Martin company; this flax was dew-retted conventionally over 6 weeks and then scutched and hackled. Then, it was wet spun by Safilin Pionki (Poland) with a metric number and twist of 9.5 km/kg and a twist of 320 tpm.
Sampling strategy	No statistical method was used to predetermine the sample size due to the low quantity of available old flax. As described below in reproducibility section, for all considered techniques, the authors have done their best to optimize and increase the number of measurement as much as possible, with regards to the preciousness and low available quantity of the old flax samples.
Data collection	Data collection was carried out by Alessia melelli, PhD student, with the softwares previously cited in software and code section.
Timing and spatial scale	For each experimental technique, sampling was done in the same period for old and modern flax, in order to avoid bias in the measurements and in particular for AFM measurements for which it is preferable to use the same tip and the same acquisition period for calibration reasons. The acquisition periods are the following: SEM: 25 September 2019 SHG: 15 January 2020 AFM: 27-29 November 2019 Nanoindentation: 19-20 November 2019 FTIR-ATR: 21 January 2020 Nanotomography: 27 January 2020 XRD: 17-18 December 2019 NMR: 7-29 November 2019
Data exclusions	No data were excluded from measurements.
Reproducibility	For SEM and SHG images, at least 5 areas were investigated and most representative images selected for publication; extra images are available upon request to the corresponding author. XRD and NMR analysis were performed on one piece of yarn, for NMR, 2000 accumulation scans were acquired for each sample and XRD analusis was performed on three distinct areas of the considered yarn. Nano Tomographic images were acquired from a measured volume of 0.5 mm in diameter over a height of 0.8 mm with a resolution of 500 nm. In order to minimize the measurement noise, each projection obtained was the result of the averaging of 15 acquisitions Regarding AFM measurements, Two to three different areas of each sample (old and modern respectively) were measured to obtain a better statistic but only one representative area for each sample is reported in this paper (Fig. 4, Supplementary Figs. 4 and 5). Supplementary Figure 4 shows the topographic images corresponding to investigated areas of Figure 4. To obtain the indentation modulus values, the entire surface of the secondary S2 (or G) wall of each fibre was selected; indentation modulus data were calculated for each point. Consequently, for each sample, the indentation modulus calculated were obtained from two or three separate images and from between 80,000 and 140,000 points for each image analysed. Figure S5 shows the calculation mask, covering the investigated area for fibres of Figure 4. For each sample, histograms of Figure 4 represent the data obtained from all the images analysed; 206,613 and

364,575 AFM force curves were used for old and modern flax indentation modulus calculation, respectively.
The authors have done their best to optimize and increase the number of measurement as much as possible, in regards with the preciosity and low available quantity, especially for the old flax.

Randomization: Only one sample of old flax was available due to the preciousness of the sample, consequently randomization is not relevant.

Blinding: For similar reason, blinding is not relevant here.

Did the study involve field work? ☐ Yes ☒ No

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

Materials & experimental systems

n/a	Involved in the study
☒	☐ Antibodies
☒	☐ Eukaryotic cell lines
☐	☒ Palaeontology and archaeology
☒	☐ Animals and other organisms
☒	☐ Human research participants
☒	☐ Clinical data
☒	☐ Dual use research of concern

Methods

n/a	Involved in the study
☒	☐ ChIP-seq
☒	☐ Flow cytometry
☒	☐ MRI-based neuroimaging

Palaeontology and Archaeology

Specimen provenance: The old flax sample was carefully extracted from a linen tabby which was given in 1929 by Georges Daressy, former General Secretary of the Antiquity Service in Egypt, to the Louvre Museum (Paris, France). Its provenance is unknown but this piece of shroud most likely came from a tomb, because all the textiles of ancient Egypt were found in cemeteries.
A piece of yarn about one cm long was taken from the edge of the linen tabby on March 12, 2019, at the Louvre Museum, with the authorization and under the control of the curator of the Coptic section of the Louvre Museum.

Specimen deposition: The sample is deposited and available on request at the IRDL laboratory of the University of Southern Brittany (Lorient, France).

Dating methods: The linen was radiocarbon dated in 2009 (Laboratoire de Mesure du Carbone 14, CEA-Saclay, Gif-sur-Yvette Cedex, France): it had been harvested between 2140 and 1976 BC (with 95.4% probability), during the 9th, 10th or 11th dynasties, a period known as the First Intermediate Period and the beginning of the Middle Egyptian Kingdom.

☒ Tick this box to confirm that the raw and calibrated dates are available in the paper or in Supplementary Information.

Ethics oversight: The study protocol was guided and approved by the conservation team of the Coptic Egyptian section of the Louvre Museum (Paris, France).

Note that full information on the approval of the study protocol must also be provided in the manuscript.