NETTLE FIBER (*URTICA DIOICA*), BETWEEN MYTH AND REALITY

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REZUMAT. În contextul prezent, de focalizare a studiilor de specialitate spre reevaluarea fibrelor naturale, a căror procesare are un impact minor asupra mediului, în comparație cu fibrele minerale compozite, analiza performanțelor mecanice și a proprietăților chimice ale fibrei de urzică conduce spre o accepție a sustenabilității sale în industria textilă contemporană. Testele de rezistență la tracțiune ale fibrei de urzică demonstrează că au un comportament care se înscrie în orientarea tipică microfibrilelor celulozice. Media proprietăților de extensibilitate este sub raportul modului Young egală cu 87 GPa, forța de rupere este 1594 MPa, și alungirea relativă la rupere de 2,11 % (tabel nr. 1). Se cunoaște prezumția generală că producția de fibrelor textile vegetale în Europa în vechime, în special ne referim la textilele țesute cu destinația de îmbrăcăminte, a fost legată de dezvoltarea agriculturii în vederea cultivării plantelor textile (în, cânepă). O investigare a unei piese vestimentare care datează din Epoca Bronzului, respectiv textila Lusehøj din Voldtofte, Danemarca, aduce noi provocări în fața acestei ipoteze. Pornind de la principiul sustenabilității meșteșugurilor tradiționale și reevaluarea lor sub cupola industriilor creative, a reciclării permanente a fibrelor din materie celulozică, având un potențial considerabil pentru a fi refolosite și remanufacturate, pentru a fi utilizate ca o sursă de stocuri de celuloză pentru produse regenerabile, prin calitatea biodegradabilității se reconsideră dintr-o perspectivă holistică viabilitatea diferitelor aplicații ale fibrelor celulozice în industria textilă – sub forma fibrei, a firului, a țesăturii și a structurii compozite.

Cuvinte cheie: fibră de urzică, proprietăți mecanice, proprietăți chimice, metode de identificare a fibrelor de urzică.

ABSTRACT. In the present context, when the focus of specialized studies are toward the reconsidering of natural fibres, whose processing has a minor impact on the environment in comparison with mineral fibre composites, mechanical performance and chemical properties analysis of nettle fiber leads to its sustainability in the contemporary textile industry and easily integrated into the permanent recycling process.

Keywords: nettle fiber, mechanical properties, chemical properties, identification methods of nettle fiber.

1. INTRODUCTION

Nettle is a herbaceous plant, who knows a classification consisting of 45 of the under species. Belongs to the family Urticaceae, as well as ramie (Boehmeria nivea, Nettle) and belongs to the genus Urtica. Stinging nettle (Urtica Dioica) is the most important species in Europe, it grows in fertile soils and can reach 1.20 meters high (Fig. 1, Fig. 2).

Nettle fiber and other urticacee fibres, are natural bast fibres obtained from the stems of the plants through foundry technology. We can summarize the anaerobic biological founded, which is done in standing waters or in specially designed pools. After this follows the drying of founded metters, beating, combing and, finally, the production of tow.

By processing the tow results yarns which can be used either as a sewing thread, ropes, or tissue, etc.

Anaerobic biological founded in water, based on the decay of pectic substances by the bacteria Bacillus amyllobacter, which locates on the stems and are multiplied in the water of foundry; through stomates or the cracksof stems, arrives in the bark [1].

Fig. 1. Midle vegetation period (during growth) of stinging nettle.

Fig. 2. Photo of a plant of Urtica Dioica in adulthood.

Morphological characteristics of the nettle fiber at micro levels are similar and to some extent can be confusesd with other bast fibers from the same plant group: flax (Linum usitatissimum), jute (Corchorus Capsularis), ramie (Boehmeria nivea), hemp (Cannabis sativa) – Figure 3, kenaf (Hibiscus Cannabinus) – Figure 4. Nettle fiber reveals in longitudinal section cross switches, knurled, x-shaped and rarely K, irregular seated (Fig. 5).

Fig. 3. Cross-section through hemp cell, 4X SEM sample fixation with paraffin and metacrylate

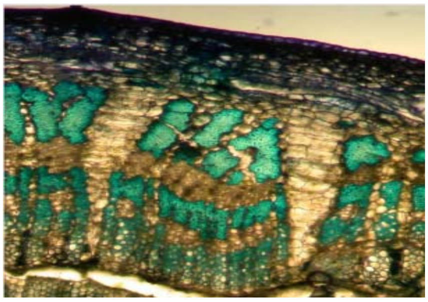

Fig. 4. Cross-section through kenaf cell, 4X SEM sample fixation with paraffin and metacrylate

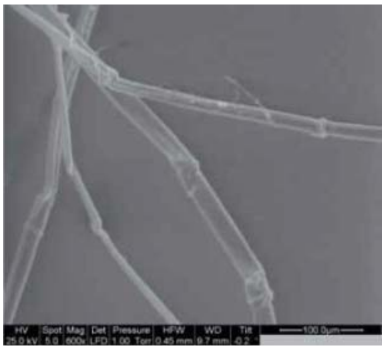

Fig. 5. Photo obtained by using SEM, nettle fibre in longitudinal section.

This morphology similar to bast fibers makes the analysis of longitudinal fibers morphology may not be conclusive in identifying the authentic way the type of fiber. That is why it is necessary and another microscopic analysis, particularly a more laborious analysis in microscopic cross section when each fiber reveals different features [2].

To identify the precise conditions of the type of fiber found in various intermediate or finished textile products will use physical and chemical methods of analysis. These methods will analyze characteristic properties in terms of physical or chemical fibre types that will be subject to certain tests.

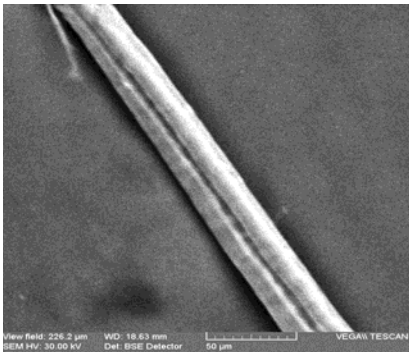

Fig. 6 SEM microphotography of nettle fiber with microfiber guidance in Visual field lighted 500 X

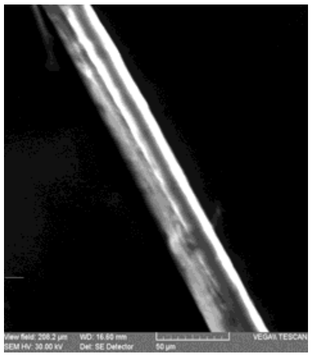

Fig. 7 SEM microphotography of nettle fiber with microfiber guidance in dark Visual field 500 X

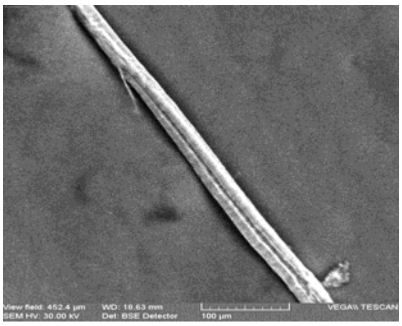

Fig. 8 SEM microphotography of nettle fiber microfiber guidance in Visual field lighted 100 X

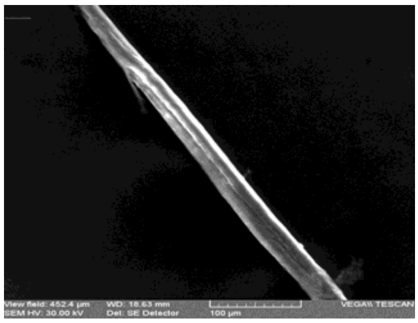

Fig. 9 SEM microphotography of nettle fiber withwith microfiber guidance in dark Visual field 100 X

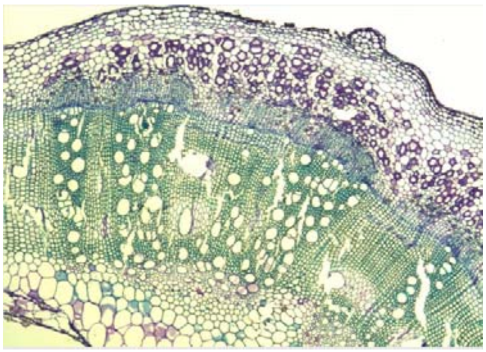

Fig. 10 Cross-section through nettle cell, 5X SEM sample fixation with paraffin and metacrylate

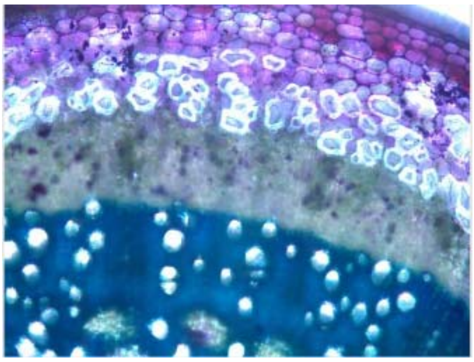

Fig.11. Cross-section through nettle cell, 10X SEM sample fixation with paraffin and metacrylate

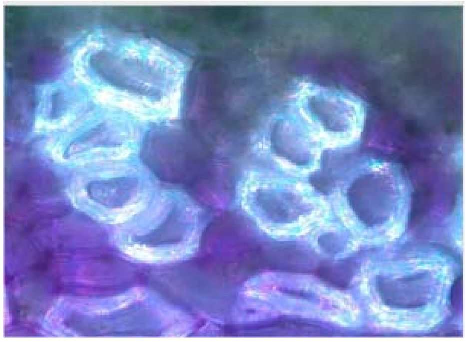

Fig. 12. Cross-section through nettle cell, 4X SEM sample fixation with paraffin and metacrylate

2. PHYSICAL AND MECHANICAL PROPERTIES OF NETTLE FIBER REGARD TO WITH OTHER BAST FIBERS.

The mechanical performances of stinging nettle fibres are measured and compared to flax and other lignocellulosic fibres. The stress/strain curve of stinging nettle fibres (Urtica Dioica) shows they have a linear behaviour which can be explained by the orientation of the cellulose microfibrils. The average tensile properties are a Young's modulus equal to 87 GPa, a tensile strength equal to 1594 MPa and, a strain at failure equal to 2.11 %

In relation to the properties of natural fibres extensibility, nettle fiber has high values, similar to that of ramie and higher to the flax values.

Single nettle fibres are glued on a slotted paper holder (10mm gap equal to L0 the nominal length of the fibre). Tensile tests are carried out on a MTS Synergie 1000 apparatus equipped with a 2N cell with an accuracy of 0.01%. The accuracy of the displacement is ±1µm. The loading speed is 1 mm/min. The ASTM D 3379-75 standard is respected throughout this study. The compliance of the system is taken into account. Before the test, each sample is observed with an optical microscope and the fibre diameter is measured. Young's modulus, stress and strain at failure are measured for 90 fibres.

Table 1 Mechanical properties of single fibres [3], [14], [15], [16]

Fiber	Young modulus [GPa]	Strain to failure [%]	Ultimate stress [MPa]	Density [g/cm^3]	Average diameter [µm]
Nellte	87	2.11	1594	0.72	20.0
Linn	58	3.3	1339	1.53	23.0
Hemp	35	1.6	389 - 900	1.07	31.2
Ramie	20 - 128	1.2 – 3.8	400 - 1000	1.56	50.0
Sisal	9-21	3-7	350 - 700	1.45	100 -300
Glass	72	3r.	2200	2.54	5 - 25

As one can see in table 1, stinging nettle fibres have a higher stiffness but lower strength and strain to failure than glass fibres. In order to compare their tensile performances, one should also take into account their density. Bearing in mind that nettle and ramie are from the same family, it is reasonable to make the assumption that nettle fibres have a density lower than glass fibres and close to 1.5g/cm³ in which case, nettle fibres would have a higher specific stiffness, strength and, strain to failure than glass fibres. [17].

Breaking force, expressed in [cN], is defined by the product of the specific resistance, P_s, expressed in [cN/mm²], [daN/mm²] and the area of the cross-section of the textile product required to stretch (fiber, yarn, knitted fabric, fabric)

$$P_R = P_s \cdot x \cdot A \text{ [cN]} \quad (1)$$

where: E - Young's modulus is calculated according to the relation 2:

$$E = \frac{F \cdot L_0}{A_0 \cdot \Delta L} \text{ [GPa]} \quad (2)$$

where: F – non-breaking force is calculated with the relation 3:

$$F = \frac{E A_0 \cdot \Delta l}{L_0} \text{ [N]} \qquad (3)$$

A_0 is the cross-sectional area of the test-piece fiber required in tension, in mm^2; ΔL is the measure by which to test-piece elongated fiber; L_0 is the length or the original.

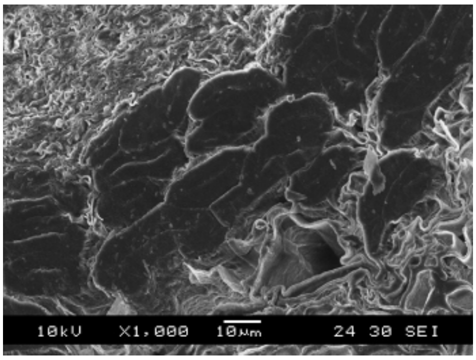

Fig. 13. SEM image of a trans-cross section of a nettle cell.

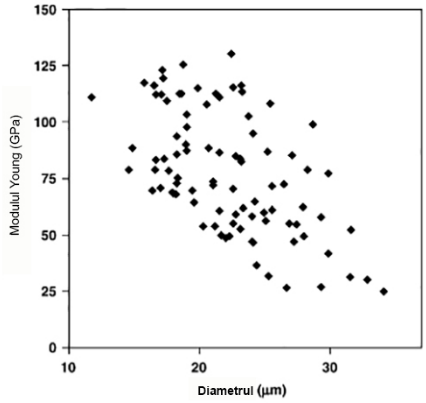

Fig. 14. Function diagram module Young in relation to the cell diameter of nettle.

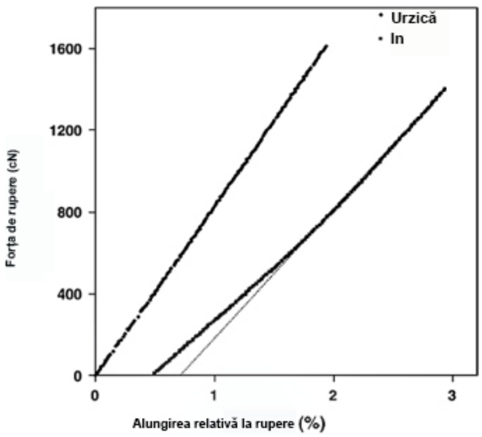

Fig. 15. Diagram depicting the comparative study between the curves of the breaking force/elongation at break relative (εt) for the nettle.

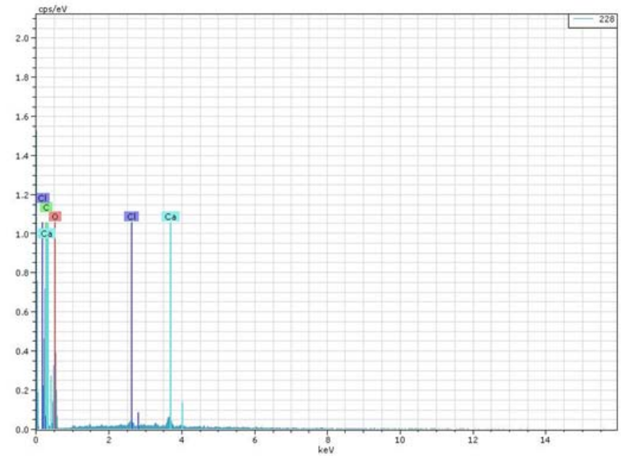

Fig. 16. The presence of the C, Cl, O, Ca atoms, in the yarn following washing.

Relative elongation at break is calculated according to the relation 4:

$$\varepsilon_t = \frac{l_f - l_0}{l_0} \cdot 100 \text{ [\%]} \qquad (4)$$

3. CHEMICAL PROPERTIES OF NETTLE FIBER AND OTHER NATURAL FIBRE OF VEGETABLE ORIGIN

Physical and mechanical properties above mentioned, as well as the technological and comfortable characteristics of textile products derived from the chemical properties of the fibres. At the base of vegetable fibers is a key component for plant fibers, cellulose, as the importance of protein fibers has a characteristic protein substances.

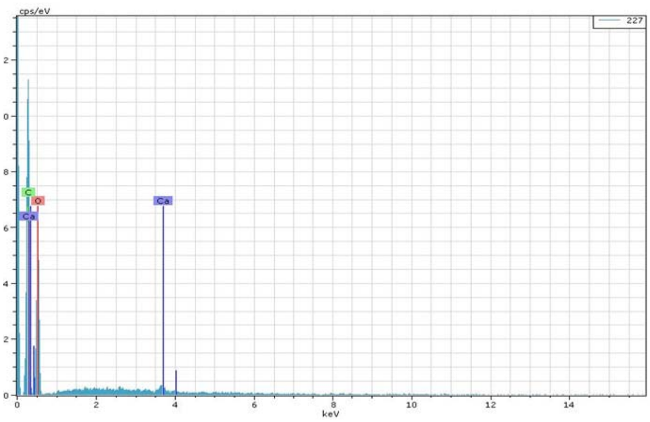

Fig. 17. The presence of atoms of C, Ca, O in nettle fibre.

Textile fibres of vegetable origin consist of cellulose and accompanying substances, for harnessing full of cotton, flax, hemp, nettle, in the textile industry, the accompanying substances, like the heavens, pectic substances, pigments, lignin, nitrogen is eliminated by cleaning and bleaching operations partially or totally depending on the aesthetic or technical feature.

Alkaline solutions, acids, oxidizing agents and cellulose fibre influence in ways determined essentially by its structure. [4].

3. 1. The Action Of The Alkalis

During finishing technology in textile materials are used alkalis in boiling processes (preliminary operation bleaching fabrics) and in operation through which it confers on textiles likely silk gloss and durable tactile qualities.

$$C_6H_7O_2(OH)_3 + NaOH \rightarrow C_6H_7O_2(OH)_2ONa + H_2O$$

By treating cellulose with NaOH solution is given a instable alchoolate called alkali-cellulose.

$$C_6H_7O_2(OH)_2ONa + H_2O \rightarrow C_6H_7(OH)_3 + NaOH$$

By simply washing with water alkali-cellulose hydrolyzes, passing in regenerated cellulose film, also called cellulose hydrate.

Cellulose hydrate is distinguished from native cellulose by reactivity, hygroscopicity, affinity towards dyes and swelling capacity increased, by the degree of polymerization and crystalline.

3. 2. The Action Of Acids

Concentrated mineral acids destroy much more cellulose fibers as the duration and operating temperature are higher. They transform the cellulose in hidrocellulose, lacking in strength, and near misses, transforms it into glucose.

$$(C_6H_{10}O_5)_nC_6H_{12}O_6 + H_2O \rightarrow nC_6H_{12}O_6 \quad \text{(Glucose)}$$

Dilute sulphuric acid and unheated, in concentration that does not exceed 3% , does not change the status of sensitive fibres after treatment 1-2 hours.

Raw fabrics of nettle (stinging nettle), by treating with nitric acid, with 50-70% concentration, on normal temperature for 1-2 hours, obtain a tactile characteristic of wool (finishing).

Between mineral acids, hydrochloric acid produces hidrolysing action, the most vivid, and phosphoric acid, the mildest hidrolysing action.

Organic acids, with the exception of oxalic acid have a destructive influence. Therefore, in practice, you would use the current finish acids formic and acetic.

By treating cellulose with acids under certain conditions to obtain esters and ethers of great importance, for use in the pharmaceutical industry and in paints and varnishes industry.

3. 3. The Action Of Oxidizing Agents.

Oxidizing agents transform plant fibres in a mixture with cellulose oxidation products as it is called oxicellulose.

Ex.: oxidizing action of chromic acid is limited to primary alcohol groups of cellulose, which turn them into aldehidique groups.

Action of sodium hypochlorite move beyond groups aldehidique to carboxiliques groups.

In conclusion, acidic or alkaline and the presence of metals with catalytic role influences the degree of oxidation of cellulose by different oxidizing substances. Finishing technology in textiles currently wears lime chloride, sodium hypochlorite, calcium hypochlorite, hydrogen peroxide, sodium peroxide, in order to bleach plant raw fabrics, from which the following different types of oxicellulose formation resulting from the cellulose reactivity substances above referred to.

4. IDENTIFICATION OF URTICACEE FIBER

4.1. Identification Of Urticacee Fibers Using Chemical Reagents.

Nettle fiber immersed in a bath of sulphur iodide turn greenish-blue. Immersed in the zinc chloride or zinc iodide turns yellow, immersed in calcium hypochlorite, it turns red, immersed in a bath of carminic acid, light turns blue-violet [5].

4. 2. Microphotography (SEM) Of Microfiber Orientation Of Nettle Fiber.

A new method of investigation is measuring the fibrillar orientation of the fiber [6].

Fibrillar orientation of the fiber is different from the various types of native cellulose fibres, constituting an important factor of influence to mechanical properties of fibers.

Fibrillar angle of bamboo is between 2 °-10 °, of jute 8 °, of ramie and nettle fibers 7.5, of sisal 20 ° [7], and of the cotton 20°-30 ° [8].

Depending on the fibrillar angle, are influenced the strength and the rigidity of fiber constitution, together with the fibre content of cellulose, cristalinity and polymerisation.

It is generally assumed that the production of plant fibre textiles in ancient Europe, especially woven textiles for clothing, was closely linked to the development of agriculture through the use of cultivated textile plants (flax, hemp) [7]. Here we present a new investigation of the 2800 year old Lusehøj Bronze Age Textile from Voldtofte, Denmark, which challenges this assumption. We show that the textile is made of imported nettle, most probably from the Kärnten-Steiermark region, an area which at the time had an otherwise established flax production. Our results thus suggest that the production of woven plant fibre textiles in Bronze Age Europe was based not only on cultivated textile plants but also on the targeted exploitation of wild plants. The Lusehøj find points to a hitherto unrecognized role of nettle as an important textile plant and suggests the need for a re-evaluation of textile production resource management in prehistoric Europe.

The new method consists of measuring the fibrillar orientation of the fibres (Fig. 18.B) using polarised light microscopy and verifying the presence of calcium oxalate crystals in association with the fibres. To ensure that the identification was done correctly a blind test was performed by testing the ancient fibre sample together with modern fibres of known origin, so that it was not known during the testing if the ancient fibre or a modern fibre was being examined. Blind testing is particularly important in an archeological context, since the uniqueness of the samples prevent measurements from being readily repeated. We found that calcium oxalate crystals were present (Fig. 18.C) and that the fibrillar orientation corresponded to an S-twist (Fig. 18.D). The combination of these two measurements proves conclusively that the Lusehøj textile is made of nettle. [10]

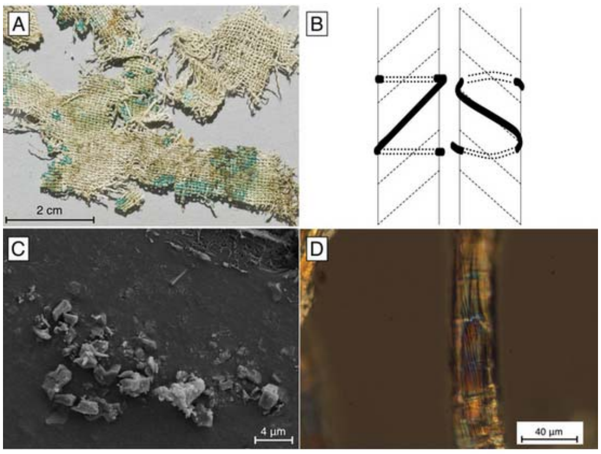

Fig. 18:
(A) The 2800-year-old Lusehøj Textile. Photo by Roberto Fortuna, The National Museum of Denmark; (B) A diagram of Z- (left) and S-twist (right); (C) Scanning Electron Microscopy image of calcium oxalate crystals found in association with the fibres. The sample has been plasma ashed to reveal the crystals. The remains of a fibre can be seen in the top right corner; (D) The fibrillar orientation in the ancient fibre is visible in a polarising microscope. As can be seen, the fibrillar orientation corresponds to an S-twist.

The strontium isotopic signature of the Lusehøj textile can correspond to several different locations with similar geological backgrounds as, for example Precambrian rocks from Sweden or Norway or the European Hercynian or Variscan orogenies. However, based on the provenance of the bronze urn, which originally contained the textile, a plausible area of production for the Lusehøj nettle textile could also be Central Europe, in particular the Kärnten-Steiermark region, which also has a Precambrian crystalline basement with a strontium isotopic signature matching our measurements.

Fig. 20. SEM microphotography of nettle, twisted towards S.

Fig. 21. Nettle fibres partially shelled by manual processes, before removing the woody stem asperities.

Fig. 22. Nettle fibres partially shelled by manual processes, processes after successive phases of work.

Fig. 23. Fragment of woven nettle, belonging to a toweling from Neamț.

Fig. 24. Household textiles and clothing casnis obtained from Nettle fiber.

5. CONCLUSIONS

Starting from the principle of sustainability to traditional crafts and reevaluating them under the dome of creative industries, permanent recycling of fibres from cellulose matter, having a considerable potential to be reused and remanufactured, to be used as a source of cellulose for renewable products, quality of biodegradability reconsider from a perspective of different applications of holistic viability of cellulose fibers in the textile industry-in the form of fiber , yarn, fabrics and structure of composite materials. [12]. The textile industry also is turning to natural fibres, such as nettle, which have high quality of psycho-sensory comfort.

REFERENCES

[1] Gheorghe Bălteanu şi colectiv de autori, *Fitotehnie,* Editura Didactică și Pedagogică, București,

[2] Zaharia, Florica, *Textile tradiționale din Transilvania. Tehnologie şi estetică,* Accent Prinț, Suceava, 2008

[3] E. Bodros, C. Baley, *Study Of The Tensile Properties* Of Stinging Nettle Fibres (URTICA Dioica), *Composite Part A*, Vol. 33, No. 7, pp 939-948, 2002

[4] Iosif Ionescu-Muscel, *Fibrele Textile,* Editura tehnică, Bucureşti, 1978

[5] Salvatore Lorusso, Luciano Gallotti, *Carraterizzazione Tecnologiae e Conservazione dei Manfatti Tessilli,* Tipolitografia Maula Biella

[6] Haugan E., Holst B., *Determinig the Fifrilar Orientation of Bast Fibres with Polarized Light Microscopy,* J. Microsc. 252 (2), 2013

[7] Blackburn R.S., editor. *Biodegradable and sustainable fibres. Cambridge: Woodhead Publishing Series in Textiles*: 47, The Textile Institute; 2005

[8] Morton W.E., Hearle J.W.S.*Physical Properties of Textile Fibres*. Manchester: The Textile Institute;

[9] Barber, E. J. W., *Prehistoric Textiles,* Princeton University Press, New Jersey, 1991

[10] Gleba, M.; Mannering, U., *Textile and Textile Production în Europe from Prehistory to AD 400, Ancient textiles Serie 11*, Oxford, Oxbow Books, 2012

[11] ***, *Nuovo Dizionario Tecnologico*

[12] Dogan Y., Nedelcheva A. M., Obratov-petkovicD., Pădure I. M., *Plants Used în Traditional Handcrafts în Several Balkans Countries,* Ind. J. Tradisional Knowl 7(1), 2008

[13] E. Bodros, C. Baley, *Investigation of the use of stinging nettle fibres (Urtica Dioica) for composite reinforcement: study of the single fibre tensile propertie*. In *Progress*

[14] D. Nabi Saheb, JP. Jog, *Natural fibre polymer composites: a review. Advances în Polymer Technology*, Vol. 18, No. 4, pp 351-363, 1999.

[15] Ishikawat et al. *Determination of parameters in mechanical model for cellulose III fibre, Polymer*, Vol. 39, No. 10, pp 1875-1878, 199

[16] LY. Mwaikambo, *MP. Ansell, The effect of chemical treatment on the properties of hemps, sisal, jute and kapok for composite reinforcement. Die Angewandte* 17. Makromolekulare Chemie, Vol. 272, No. 1, pp 108-116, 1999

[17] Beukers, Van Hinte Editor. Rotterda, *010 Publishers*, 1999.

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