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NATURAL FIBERS AND SUSTAINABILITY IN FASHION: COMPARATIVE ANALYSIS OF TEXTILE TEST WITH HEMP, JUTE AND LINEN

FIBRAS NATURAIS E SUSTENTABILIDADE NA MODA: ANÁLISES COMPARATIVAS DE ENSAIOS TÊXTEIS COM CÂNHAMO, JUTA E LINHO

FIBRAS NATURALES Y SOSTENIBILIDAD EN LA MODA: ANÁLISIS COMPARATIVO DE PRUEBAS TEXTILES CON CÁÑAMO, YUTE Y LINO

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ABSTRACT

Natural fibers date back to ancient times. Hemp is one of the oldest textile fibers in human history, with records of use dating back to 207 BC, particularly in Eastern civilizations such as China and India. With remarkable physical and mechanical properties—strength, durability, flexibility, and high environmental performance—this plant fiber is currently at the center of contemporary debates on sustainability principles in the fashion industry, especially in contrast to the impacts of fast fashion. This study adopts an exploratory and practical methodological approach, based on morphological analyses and burn identification tests to compare the performance of hemp (CH), flax fiber (CL), and jute (CJ). The aim is to understand the specific potential of these raw materials, whether used alone or in blends with other fibers, highlighting their strategic role in repositioning the fashion production chain from an environmentally responsible perspective.

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Keywords: Natural Fibers. Sustainability. Textile Morphology. Production Chain.

RESUMO
As fibras de cunho natural datam de tempos remotos, o cânhamo configura-se como uma das fibras têxteis mais antigas da história da humanidade, com registros de uso desde 207 a.C., sobretudo nas civilizações orientais, como a chinesa e a indiana. Com propriedades físico-mecânicas notáveis — resistência, durabilidade, flexibilidade e alta performance ambiental —, essa fibra vegetal no tempo presente está no centro dos debates contemporâneos sobre preceitos da sustentabilidade na indústria da moda, especialmente em contraponto aos impactos provocados pela moda fast fashion. Este estudo adota uma abordagem metodológica de cunho exploratório e prático, ancorando-se em análises morfológicas e testes de identificação por queima, para comparar o desempenho do cânhamo (CH), fibra do linho (CL) e juta (CJ). Objetiva-se, assim, compreender as potencialidades de cunho especifico destas matérias-primas, isoladamente ou em mistura com outras fibras, evidenciando seu papel estratégico no reposicionamento da cadeia produtiva da moda sob uma perspectiva ambientalmente responsável.

Palavras-chave: Fibras Naturais. Sustentabilidade. Morfologia Têxtil. Cadeia Produtiva.

RESUMEN
Las fibras naturales se remontan a la antigüedad. El cáñamo es una de las fibras textiles más antiguas de la historia de la humanidad, con registros de su uso que datan del año 207 a. C., especialmente en civilizaciones orientales como China e India. Con notables propiedades físicas y mecánicas (resistencia, durabilidad, flexibilidad y alto rendimiento ambiental), esta fibra vegetal se encuentra actualmente en el centro de los debates contemporáneos sobre los principios de sostenibilidad en la industria de la moda, especialmente en contraste con los impactos de la moda rápida. Este estudio adopta un enfoque metodológico exploratorio y práctico, basado en análisis morfológicos y pruebas de identificación de quemaduras para comparar el rendimiento del cáñamo (CH), la fibra de lino (CL) y el yute (CJ). El objetivo es comprender el potencial específico de estas materias primas, ya sea utilizadas solas o en mezclas con otras fibras, destacando su papel estratégico en el reposicionamiento de la cadena de producción de la moda desde una perspectiva ambientalmente responsable.

Palabras clave: Fibras Naturales. Sostenibilidad. Morfología Textil. Cadena de Producción.

1 INTRODUCTION

Since the dawn of humanity, the development of fibers, yarns, fabrics and knits, as well as textile processing processes, has played a fundamental role in the history of manufactures. As Vasques (2011, p. 30) observes, "the textile product is one of the oldest manufactures of man, because man has always intertwined palm leaves, tanned and sewed the skins to use on his body". With the evolution of technical knowledge and the diversification of raw materials, human beings have improved their ability to manipulate fibers, transforming them into textile structures. A classic example of this advance is the elaboration of flat fabric.

> The technique used for the transformation of fabric is done with the crossing of weft (horizontal direction) and warp (diagonal direction) threads. However, with the advent of technology, industrialization and increased trade, the textile market gained considerable space and, as production and consumption grew, the modernization of the mechanization of operations accelerated (Vasques, 2011, p.30).

It is important to highlight that, in order to understand the functioning of the textile production chain, it is necessary to elucidate the stages involved in its transformation. The process begins with textile fibers — natural or artificial — which go through spinning (production of yarns), go on to weaving (production of flat fabrics) or knitting (production of knitwear), and end in finishes, also called processing. Cellulosic fibers, in particular, have been widely used, often being combined and processed in different ways. In view of this, it is worth reflecting on how these transformations occur today and what practices have been adopted by the industry.

> The Textile Industry has been pointed out as one of the most polluting industries today, resulting in several negative externalities, as a consequence of the emergence of the so-called fast-fashion (Martins, 2022, p.11).

Corroborating with environmental issues, it is necessary to adopt new methods for consumption. Replacing the production of clothes made of artificial and synthetic fibers, through natural fibers that are more sustainable or even that has sustainable practices in their cultivation until the final product. Hemp is a fiber of great interest to the textile industry, due to its mechanical and physical properties, but also due to its low environmental impact (Rani et al., 2020 apud Mariz, 2023, p. 12). Hemp is an annual plant, which can reach up to 5 meters in height, and is well known for its effectiveness in using sunlight in photosynthesis. (Oliver, 1999). Hemp reacts best to semi-humid regions with an average temperature of 14 to 27 degrees Celsius, needing plenty of rain/irrigation (especially in the first 6 weeks), being

resistant to drought after days, but resulting in mass reduction and acceleration of plant maturity (Oliver, 1999).

Hemp fiber has always been linked to the textile area, having its first traces of textile applications around 207 BC, mainly explored by China and India. They are fibers considered strong, therefore, widely used in nets and ropes throughout its history (Martins, 2022). Other advantages of hemp is its great water resistance and flexibility, thus having a good relevance in the marine trade and fishing sectors. Considering the physical and chemical properties. Fiber has always been the main form of hemp use. Some of the most common uses of fibers are: plastic, biofuel, paper, concrete, acoustic insulation materials, and thermal insulation (Delfino, 2021).

In the twentieth century, it was little used in the fashion industry for fibers such as cotton (CO) and linen (CL), due to the fact that it was a fiber that required a greater amount of labor and the slow industrial process than other fibers, for example, artificial and synthetic fibers.

> The oldest fibers are considered reeds, linen (CL) and hemp (CH), Hemp comes from the Latin cannabis, which gave the name of the fabric canevas or canvas, which comes to be canvas, denim, hemp It serves, in addition to the most common uses, for embroidery work, tapestries and was at the time of the Inquisition with punishment in shirts directly worn on the skin, called cilice, or even as penance for the fearful (Chataignier, 2006, p. 28).

Documents regarding the cultivation of hemp in Europe are relatively scarce until the fifteenth century, when the importance of this species, mainly as a fiber crop for the production of textiles and ropes, grew and reached an important and well-documented commercial role between the eighteenth and nineteenth centuries (Amaducci et al., 2015). Due to the commercial difficulties that the metropolis had been experiencing, Saad states (2013, p.03) "In 1783, the Royal Feitoria do Linho Hemp was installed in Rio Grande do Sul, one of the projects promoted by the Portuguese State with the objective of strengthening the economy of its largest colony".

Industrial hemp had a drop in production and there are some factors that explain what caused this. The main one is due to its connection with the cannabis plant, resulting in a prejudice and judgment with the various applications that this plant offers, in addition to the large-scale production of alternative fibers, the rivalry in profitability, absence of qualified means of production, machinery and technology essential for reducing costs, contribute to the decline in the markets (Martins, 2022). Nowadays, the country that produces the most

hemp is China, followed by the United States and Canada. Having continuous growth in Europe, in countries such as France, Romania and Ukraine.

Hemp is an annual plant, which can reach up to 5 meters in height, and is well known for its effectiveness in using sunlight in photosynthesis (Oliver, 1999).

1.1 JUTE

Jute fiber (CJ), whose scientific name is Corchorus capsularis, which comes from the Tilioideae family, has a great potential for application in the textile industry (Silva, 2014). The species are: Chorchorus L., reaching three to five meters in height, and Corchorus olitorius L., reaching one to four meters in length, being the first most important from a textile point of view (Maia, 2009).

Jute (CJ) is grown in humid and tropical climates in the north of the country, producing a fiber of high strength, low cost, malleability and abundance (Silva, 2014). The plant has a stalk with a thickness of approximately 20 mm, and the extraction is done by maceration, without the use of pesticides or fertilizers (Silva, 2014). Having benefits from the high temperatures of the regions where they are grown, helping in fermentation making it possible to macerate in 8 to 10 days, thus facilitating the removal of the bark from the plant and the separation of the fibers from the woody part of the stalk (Silva, 2014).

The best quality Jute (CJ) are those with robust fibers, the white and shiny color of the stalk and those of lower quality have darker stalks and less long fibers of grayer color, also having a lack of resistance (Maia, 2009).

1.2 LINEN (CL)

Flax (CL), whose scientific name is Linum usitatissimum , is a herbaceous plant that belongs to the linaceae family (Souto, 2009). Being able to reach up to one meter in height, the ideal for the cultivation of this plant is preferably in regions with temperate climates and in fertile soils abundant with water, flax (CL) is composed of a fibrous substance, from which long fibers are extracted for the manufacture of fabrics and a woody substance (Souto, 2009). It can be classified as a natural fiber, of vegetable origin, obtained from the stem of plants of the Linaceae family (Souto, 2009). Linen fabric is durable and resistant, and when wet it can have 20% more resistance than in its normal state, linen does not shrink or widen (Pezzolo, 2021).

In this way, we know the origin and stories of three natural fibers, the fiber of Hemp (CH), Jute (CJ) and Flax (CL), important from their first traces of textile applications from antiquity to the present time.

2 THEORETICAL FRAMEWORK

This chapter is dedicated to the analysis of hemp fiber (CH), focusing on four fundamental aspects: its historical and geographical origin, the processes and equipment used to extract the fiber, the stages of transformation into knitted fabrics and, finally, its application and relevance in the contemporary fashion industry.

2.1 ORIGIN AND CHARACTERISTICS OF HEMP

Hemp, "Herbaceous plant of the cannabidaceae family (Cannabis sativa), cultivated for its stem that provides the excellent textile fiber of the same name." (Pezzolo, 2012, p.123). It was once classified as Moracea and Urticaceae, but are now widely accepted as belonging to its own family. (Fleming; Clarke, 1998). The main characteristics of the plant itself are great flexibility to climates, it grows in a short period of time, does not need pesticides, just good fertilization and enriches the soil after harvests due to its ability to absorb heavy metals.

Hemp originates from Central Asia, found in the early Neolithic period (between 7,000 and 2,500 BC), it is possible to be one of the oldest domestic plants in history, having an average of more than 10,000 years of consumption. Eventually, hemp diversified across distinct regions around the world. Spreading throughout the African continent, later, through Europe (Rosa, 2018). This is due to their way of cultivation, mentioned earlier.

Between the mid-years 1747 and 1824, several initiatives were undertaken in Brazilian regions by the Portuguese empire, such as Rio Grande do Sul, Santa Catarina and Pernambuco, trying to introduce the cultivation of hemp in the country (Rosa, 2014). All the projects are characterized as projects of the Portuguese Empire, however, despite all the efforts of the Crown in relation to cultivation, they did not cause the desired effect (Rosa, 2019).

> In Brazil, the stimulus to the cultivation of hemp linen began when, in the mid-eighteenth century, the Portuguese Empire sought alternatives for the manufacture of fabrics, sails and ropes (SAAD, 2013, p. 02).

It should be noted that historically the cultivation of Flax (CL) in Brazil occurred in the states of Rio Grande do Sul, Santa Catarina and Pernambuco. And how did the machinery for its extraction come about?

2.2 HEMP EXTRACTION AND HARVESTING MACHINERY

It is necessary to highlight that the harvest time of hemp for the final use of the fiber is of paramount importance, aspects such as good yarn separation and quality are extremely

important (Kramer, 2017). There are two methods of harvesting, commonly used in Europe. The first is called whole stem harvesting, where the entire plant is taken for the next processing steps, this technique produces a longer fiber, but the necessary machinery is difficult to find (Kramer, 2017). The second method, on the other hand, is more used, named as harvesting the cut stem, where it is separated or crushed into different sections, reducing the quality of the fiber (Kramer, 2017). There are two types of maceration, the first being field maceration. The hemp plantation is monitored regularly, the stems are left in the field for 4 to 6 weeks. It is a cheap and ecological method, due to the low labor and the non-use of water. The second process is water maceration, the stems are gathered after the coolheita process, in bundles of fibers and immersed in water. This method results in more uniform fibers, with high quality. (Kramer, 2017)

The first step in extracting fibers from hemp is maceration, breaking down pectins (polysaccharides formed by galacturonic acid monomers joined by glycosidic bonds) that bind the fibers together using natural chemicals, bacteria, or fungi (Duque et al, 2020). Then, the stem needs to be broken, so they use a breaker or fluted rollers breaking the core into small pieces, it is a process called breaking, followed by stripping (separation of the fibers of a textile plant from cellulose), (Duque et al, 2020). The short and long fibers are separated, passing the fiber bundles through rubber belts, being transported to rotating drums, this process can be carried out in a machine called decorticator (removes plant stems), (Kramer, 2017).

2.3 TEXTILE PRODUCTION IN KNITTING WITH HEMP FIBRES

Through exploratory research, a bibliographic survey of primary and secondary sources was carried out (Tomé, 2023). The study was also a modality of qualitative research, where it was used to investigate how the company Dalila Ateliê Textil imports hemp fiber and how the process is used in the production of this type of knit (Tomé, 2023).

The company Dalila Ateliê Têxtil founded more than thirty years ago, by Mr. José da Silva and Dona Everli (Tomé, 2023). At first they were just a small children's fashion factory, which over the years became a large circular knitting shop (Tomé, 2023)." Its headquarters for breeding and beginning the creation of raw mesh is located in Jaraguá do Sul/SC, and the processing and logistics sector is located in Presidente Getúlio/SC, adding up to about 600 employees in the two plants" (Tomé, 2023, p. 09).

The company manufactures differentiated knitwear, finding innovation, technology, sustainability, and environmental preservation as fundamental axes (Tomé, 2023).

Dalila Ateliê Têxtil invests a lot in natural fibers, starting at first, with defibered yarns,

where they are transformed into new fibers to create new knitwear, resulting in a new proposal, the hemp knit, which drives sustainability through actions and products (Tomé, 2023).

In the 2022 collection, it was when they managed to put this production into practice, with 85% cotton and 15% hemp in the knitted fabric with a weight of 160g/m2, the sweatshirt with 74% cotton and 26% hemp, with a weight of 330g/m2 (Tomé, 2023).

2.4 HEMP IN FASHION

"The "hemp" fashion has had great success in some countries, with stores specializing in clothing produced with hemp, among them, we can mention EcoWear" (Alves, Ruthschilling, 2008, p. 05).

The production of textile materials is responsible for generating waste that impacts the environment, being one of the sectors that cause the most damage, for this reason they seek alternatives to change this perspective, investing in research and innovation (Almeida et al, 2021). It can be considered that the fertilization and planting phase is one of the main sources of environmental impact, as well as weaving and dyeing (Almeida et al, 2021). The cultivation of vegetable fibers can be one of the alternatives to soften the negative impact that this sector causes, although they are still little disseminated in Brazil, hemp fiber can be considered an alternative for textile production. (Almeida et al, 2021).

Hemp is one of the strongest and most resilient organic plant fibers, it is unmatched in durability, resilience, antimicrobial, antifungal properties and is UV resistant as well as biodegradable, making it one of the best eco-conscious fibers in the fashion industry (Cunha, 2019; Almeida et al, 2021). Its production does not need synthetic pesticides to grow, meaning that clothes produced from hemp are environmentally sustainable (Cunha, 2019)

The final fabric, in addition to having natural fiber characteristics, is durable, in the heat it remains cool and warm in winter, is able to absorb moisture from the body, the resistance is three times greater than that of cotton and with time of use the fabric becomes softer (Cunha, 2019; Almeida et al, 2021).

The Levi's brand, which has already appropriated this raw material, in partnership with textile engineers, has produced a "cotton" process that leaves the fiber with a soft touch, similar to cotton. According to Alves et. al (2008, p. 04) "The "hemp" fashion has had great success in some countries, with stores specializing in clothing produced with hemp, among them, we can mention EcoWear". Brands such as Armani, Ralph Lauren and Calvin Klein have already made collections using hemp fabric, and sports brands such as Nike and Patagonia also use it (Cunha, 2019).

In this way, hemp (CH) stands out as a textile fiber with high technical performance and low environmental impact, bringing together attributes that qualify it as a sustainable alternative. Its incorporation into the fashion industry represents a significant step towards more responsible practices that are aligned with the principles of sustainability.

3 METHODOLOGY

This study adopts an exploratory, descriptive and practical approach. The theoretical stage consisted of a bibliographic survey based on already published sources, including books, scientific articles and publications in specialized databases, addressing hemp fiber (CH), the principles of sustainability, the textile production chain and the recent developments of this fiber in fashion, especially in the last five years.

In the practical scope, yarns from brands that incorporate hemp (CH) pure or in mixtures were analyzed, with the aim of identifying and comparing the use of cellulosic fibers, also including samples of linen (CL) and jute (CJ) fabrics. To this end, tests were carried out to identify the origin of the fibers through the burn test and the textile morphological analysis with the use of an electronic yarn counter, both conducted in the Fabric Library Extension Project, linked to the collection of textile flags of the University in the Fashion course.

4 RESULTS AND DISCUSSIONS

The table with the results of the tests performed is presented below, covering the following parameters: behavior in the burn test, density, coloration, tactile characteristics (sensory touch), fiber composition, type of interlacing, fabric structure and construction method. Next, the textile morphological analyses of the samples are exposed, with the identification of the right and reverse sides of the tissues examined.

Table 1

Tests carried out in the textile laboratory, in the fashion workshop, room 05, of the Fashion course at UEM – Regional Campus of Cianorte (CRC)

	Hemp (CH)	**Jute (CJ)**	**Jute Wire (CJ)**	**Linen (CL)**
Density				
Colour	White	Ochre	Ochre	Mustard yellow
Sensory Touch	Rough.	Dry, rough and rustic.	Dry, rough and rustic.	Dry and rough.

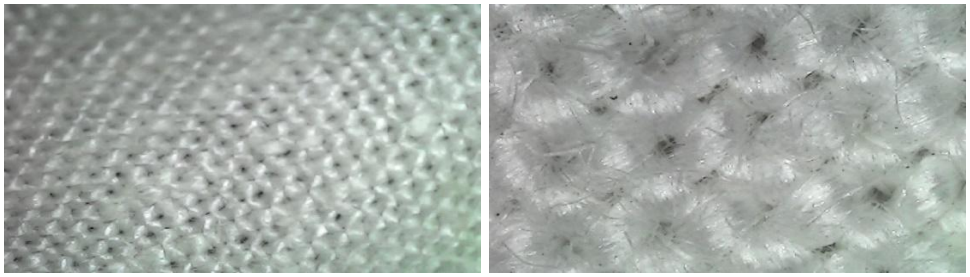
Test the burn	It burns like paper, paraffin, ashes and natural.	Burns fast, weeds, ashes and cellulosic.	Burns slowly, paper, ashes and cellulosic.	It looks synthetic, charcoal, brittle, and natural.
Composition	Fiber blends	100% jute (CJ)	100% jute (CJ)	100% linen (CL)
Connection type	1x1 (Screen)	1x1 (Screen)	Not applicable	1x1 (Screen)
Fabric Type	Natural and flat	Natural and flat	Natural	Natural and flat
Construction method	Industrial	Industrial	Industrial	Industrial

Source: Fabricteca Extension Project (collections of textile flags).

The morphological tests (figures 01 to 07) carried out in the Laboratory of the Fabricteca (block y03, room 03), Regional Campus of Cianorte (CRC) are below.

Figure 1

Electronic yarn counter - Hemp shirt (CH), right side



Source: Tecidoteca, 2025.

Figure 2

Electronic yarn counter - Hemp shirt (CH), wrong side

Source: Tecidoteca, 2025.

Figure 3

Electronic wire counter – Jute Tape (CJ)

Source: Tecidoteca, 2025.

Figure 4

Electronic yarn counter – Jute Fabric (CJ), right side

Source: Tecidoteca, 2025.

Figure 5

Electronic yarn counter – Jute Fabric (CJ), reverse side

Source: Tecidoteca, 2025.

Figure 6

Electronic yarn counter – Linen fabric (CL), right side

Source: Tecidoteca, 2025.

Figure 7

Electronic yarn counter – Linen fabric (CL), wrong side

Source: Tecidoteca, 2025.

Figure 8

Hemp Gaiter

Source: Tecidoteca, 2025.

The morphological analysis of the flat fabrics and yarns revealed relevant similarities between the natural fibers investigated, especially with regard to composition, manufacturing methods, tactile characteristics and behaviors observed in the burning tests, among other technical attributes. Considering the comparative analysis of textile trials with Natural Fibers to be very valid, from the perspective of sustainable practices in the Fashion production chain.

5 FINAL CONSIDERATIONS

The comparative analysis between the natural fibers of hemp (CH), jute (CJ) and flax (CL), under the technical and morphological bias, allowed to highlight the potential of hemp as a viable and promising alternative for a more sustainable fashion. The physicochemical characteristics of hemp, such as high strength, flexibility, durability and low environmental impact — are compatible with the demands of contemporary industry, especially those aimed at ecologically-based innovation.

The laboratory tests carried out, especially the burning tests and morphological analysis under electronic yarn count, confirmed the viability of hemp as a textile fiber applicable in various configurations. It was also found that hemp has a competitive

performance against the other cellulosic fibers analyzed, and that its use in hybrid compositions expands possibilities of application in fashion and textile design.

The case study in the textile industries reinforces this perspective, by demonstrating that it is possible to integrate hemp into industrial processes through innovative practices that combine tradition, sustainability and technology. However, although there has been progress in the insertion of hemp in the market, challenges still persist related to technical culture, the standardization of processes and the overcoming of historical stigmas linked to the plant in Brazil.

It is therefore considered that the systematic reintroduction of hemp into the textile chain depends not only on investments in machinery and research, but also on a paradigmatic shift in the way fashion and sustainability are conceived. It is still necessary to problematize in more depth the mixed use of natural fibers, questioning the authenticity, traceability and sustainable discourse behind these compositions. Thus, hemp fiber is configured not only as a technical solution, but as a critical agent of transformation for 21st century fashion. And, finally, it is proposed to carry out future research aimed at the comparative analysis of natural fibers in the textile sector, with emphasis on the three raw materials studied here: hemp, jute and linen, considering a sustainable approach and consistent with the real demands of contemporary industry.

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