

Characterization of Regular Polyamide 6.6 and Biodegradable Polyamide 6.6

Caracterização de Poliamida 6.6 Regular e Poliamida 6.6 Biodegradável

Caractérisation du Polyamide 6.6 ordinaire et Polyamide 6.6 biodégradable

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Abstract

This study aimed to conduct a comparative analysis of conventional polyamide 6.6 and biodegradable polyamide 6.6, focusing on their physicochemical properties. To achieve this, a literature review was carried out, along with technical visits and interviews (involving qualitative data collection from industry professionals) with the Brazilian producer of both fibers (Rhodia, part of the Solvay Group). Additionally, laboratory tests were conducted on yarns and knitted fabrics made from these two polyamides. The tests included breaking elongation, tenacity, moisture regain, and fabric weight measurements, and FTIR-ATR spectroscopy. No significant differences were found. Although biodegradable polyamide 6.6 promises environmental benefits, these could not be confirmed within the scope of this study. It is concluded that further research is necessary to validate its sustainable impact in practice.

Keywords: polymers (materials). sustainability. biodegradation.

Resumo

O presente estudo teve como objetivo analisar comparativamente a poliamida 6.6 regular e a poliamida 6.6 biodegradável, com foco em suas propriedades físico-químicas. Para isso, foram realizados levantamento bibliográfico, visitas técnicas e entrevistas (com coleta de dados qualitativos junto a profissionais da área) com a empresa produtora de ambas as fibras no Brasil (Rhodia do grupo Solvay). Além disso, foram conduzidos testes laboratoriais com fios e tecidos de malha confeccionados a partir dessas duas poliamidas. Foram realizados testes de alongamento de ruptura, tenacidade, regain, gramatura e FTIR com ATR. Os resultados não revelaram diferenças significativas. Embora a poliamida 6.6 biodegradável prometa vantagens ambientais, essas não puderam ser comprovadas nos limites deste estudo. Conclui-se que mais pesquisas são necessárias para validar seu impacto sustentável na prática.

Palavras-chave: polímeros (materiais). sustentabilidade. biodegradação.

Resumé

Cette étude avait pour objectif d'analyser de manière comparative le polyamide 6.6 conventionnel et le polyamide 6.6 biodégradable, en se concentrant sur leurs propriétés physico-chimiques. Pour ce faire, une revue de la littérature a été réalisée, ainsi que des visites techniques et des entretiens (incluant une collecte de données qualitatives auprès de professionnels du secteur) avec l'entreprise brésilienne productrice des deux fibres (Rhodia du groupe Solvay). De plus, des tests en laboratoire ont été menés sur des fils et des tissus tricotés fabriqués à partir des deux polyamides. Les essais ont porté sur l'allongement à la rupture, la ténacité, la réhumidité, le grammage et la spectroscopie FTIR-ATR. Les résultats n'ont pas révélé de différences significatives. Bien que le polyamide 6.6 biodégradable promette des avantages environnementaux, ceux-ci n'ont pas pu être confirmés dans le cadre de cette étude. En conclusion, des recherches supplémentaires sont nécessaires pour valider son impact durable dans la pratique.

Mots-clés : polymères (matériaux). durabilité. biodégradation.

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1 Introduction

Nylon, also known as polyamide, refers to the group of thermoplastics known as aliphatic polyamides and is characterized by the amide group (—CONH—). They encompass a multitude of material types (polyamide 6.6, polyamide 6.12, polyamide 4.6, polyamide 6 and polyamide 12), which provide a wide range of properties suitable for a variety of applications, from aircraft tires to parachute fabric (Bunsell, 2009), offering high strength and abrasion resistance, good elasticity and uniformity, as well as good moisture resistance and high absorption capacity (Horrocks, 2000; Anand, 2000). These properties are noted in the manufacture of clothing, carpet backing, ropes, tire reinforcement, and other applications (Oliveira, 2009).

Polyamide represents a significant milestone in the history of synthetic fibers, as it was the first to be produced on a large scale, even before World War II. Its origin dates back to the 1920s, in the laboratories of the DuPont company, located in Wilmington, United States, under the leadership of chemist Wallace Carothers. Born in 1896, Carothers was hired by DuPont in 1928 to conduct research aimed at developing new materials, having been recognized for his remarkable previous scientific achievements (McIntyre, 2005; Kohan, 1986).

The studies conducted by Carothers and his team led to the production of macromolecules with molar masses greater than 4,000, a remarkable feat at the time, achieved through polyesterification—a process involving the reaction between diacids and glycols, with the release of water molecules as a byproduct (Trossarelli, 2010). In 1930, Carothers and chemist Berchet studied the thermal polymerization of the ϵ -aminocaproic acid, observing the formation of a mixture between polyamides and the cyclic monomer ϵ -caprolactam. Although they initially failed to obtain fibers, this was possibly due to the low molecular weight of the material (McIntyre, 2005).

Subsequently, new experiments were conducted with different combinations of dibasic acids and aliphatic diamines, resulting in polyamides with greater insolubility and higher melting temperatures compared to the polyesters synthesized up to that point (McIntyre, 2005). It was not until 1935 that Carothers effectively synthesized polyamide

6.6 from the reaction between hexamethylenediamine and adipic acid. This development led to the first patent for a synthetic fiber, and its commercialization was officially announced by DuPont in 1938, with industrial-scale production commencing in 1939 (Bunsell, 2009). The new fiber became known by the trade name nylon, a name that has become established over time (McIntyre, 2005).

Shortly after the development of polyamide 6.6, polyamide 6, also known as nylon 6, was invented by Paul Schlack at IG Farben in Germany in 1938. It was developed as an alternative to polyamide 6.6, seeking to circumvent DuPont's patents. It is obtained through the polymerization of caprolactam, a 6-carbon cyclic amide, which presents itself as a colorless crystalline solid and serves as a monomer for the production of polyamide 6 (McIntyre, 2005). It is currently imported and consumed in Brazil together with polyamide 6.6.

Both polyamides (6.6 and 6) are synthetic polymers with a chain molecular structure, formed by repeated amide groups. They are known for their strength, durability, and versatility, which make them essential materials in various industries, including the textile industry (McIntyre, 2005). Both are lightweight, soft fibers that have a low degree of shrinkage, high elasticity, resistance to wear, dry quickly, have low thermal conductivity, and moderate capacity to absorb body perspiration, in addition to being well accepted for textile finishes. They are well-suited for the manufacture of underwear, swimwear, socks, and fitness fashion items (Oliveira, 2009).

In Brazil, the production of polyamide 6.6 with biodegradable properties only began in 2014, led by Rhodia, a Solvay group company (Solvay, 2024), whose characteristics will be discussed in more detail later.

In light of the growing debate surrounding environmental sustainability, which has raised questions about the impact of synthetic fibers on product life cycles, particularly regarding their fossil origin and persistence in the environment, there is interest in studying biodegradable polyamide 6.6 in relation to conventional polyamide 6.6.

In this context, the present study aimed to analyze data in the literature on the properties of regular polyamide 6.6 and biodegradable polyamide 6.6, followed by comparative physical-chemical tests between their yarns and knitted fabrics (produced from these yarns) through tests of elongation at break, tenacity, regain and basis weight, in addition to FTIR testing with ATR.

2. Properties of Regular Polyamides 6 and 6.6

The mechanical properties of both polyamide 6 and 6.6 depend on their molecular weight and the weight distribution of the polymer chains, together with their morphological structure, chain orientation, and the degree of fiber order. Spinning, drawing and heat treatment conditions significantly influence the morphological structure (Horrocks, 2000; Anand, 2000; Richards, 2005). **Table 1** shows the physical and chemical properties of regular polyamides 6 and 6.6.

Table 1 - Physicochemical properties of regular polyamides 6 and 6.6

Properties	Polyamide 6	Polyamide 6.6
Tenacity (cN/tex)	45-90 (540-1080 MPa)	55-90 (600-1080 MPa)
Breaking Elongation (%)	15-40	15-30
Young's Modulus (cN/tex)	150-500 (1800-600 MPa)	250-450 (3000-5400 MPa)
Glass Transition Temperature (°C)	25	47
Melting Temperature (°C)	215	260
Specific Heat Capacity J/g(°C)	430	620
Limiting Oxygen Index (LOI)	20	22

Source: Adapted from (BUNSELL, 2009).

Although both polyamides have the same types of application in the textile industry (manufacture of underwear, swimwear, socks, and fitness fashion items), with differences in dye absorption in their dyeing process (Rosa, 2003; Oliveira, 2009), they have significant differences in other properties that imply different uses in other industrial

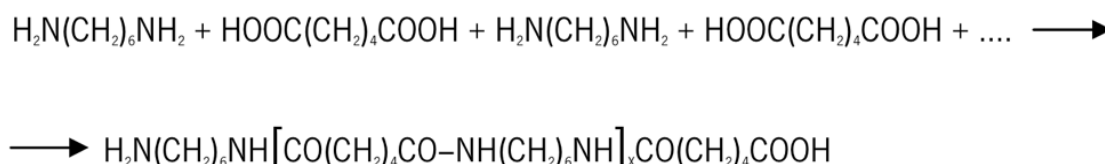
sectors. As shown in Table 1, the two polyamides differ in their melting points, with polyamide 6.6 having a higher melting point (approximately 260°C) compared to polyamide 6 (approximately 215°C), making it more suitable for high-temperature applications.

In addition, polyamide 6.6 is more rigid and impact-resistant (as evidenced by its Young's modulus values), while polyamide 6 is more flexible and exhibits better machinability. Thus, polyamide 6 is often used in parts that require flexibility and a good surface finish, such as gears, bushings and components for the electrical and automotive industries. Polyamide 6.6 is more commonly used in applications that require high mechanical and thermal resistance, such as parts for pumps, valves, and automotive components (Bunsell, 2009).

2.1.1 Regular Polyamide 6.6 (nylon 6.6)

Polyamide 6.6 is obtained through the polycondensation of 1,6-diaminohexane (or hexamethylenediamine) and hexanedioic acid, commonly known as adipic acid (Richards, 2005; Sacchi, 2016) (Figure 1).

Figure 1: Polymerization reaction of polyamide 6.6



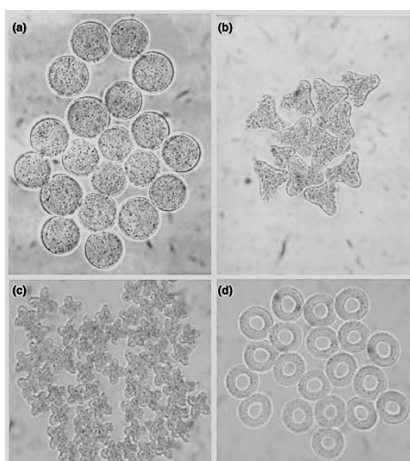
Source: (Oliveira, 2009)

In the polymerization of polyamide 6.6, adipic acid and hexamethylenediamine react together in equimolar amounts at room temperature to form “nylon salt.” The salt is prepared by mixing a dispersion of the diacid in water with the diamine solution, resulting in a 50-60% aqueous salt solution. The pure salt precipitates and is dissolved in the solution with water (Richards, 2005).

The high resistance to degradation of synthetic polyamides is attributed to the high symmetry of their molecular structures and the strong intermolecular cohesive forces resulting from hydrogen bonds between molecular chains, which leads to a highly crystalline (molecularly oriented) morphology (Sacchi; Marcicano; Vasconcelos, 2021).

Their fibers can be produced in different cross-sectional shapes. The most common are circular and trilobal (for greater shine), but the fibers can be made in other shapes depending on the application (Sacchi, 2016) (**Figure 2**).

Figure 2 - Polyamide fibers with (a) round, (b) trilobal, (c) quadrilobal, and (d) hollow cross sections.



Source: (Richards, 2005)

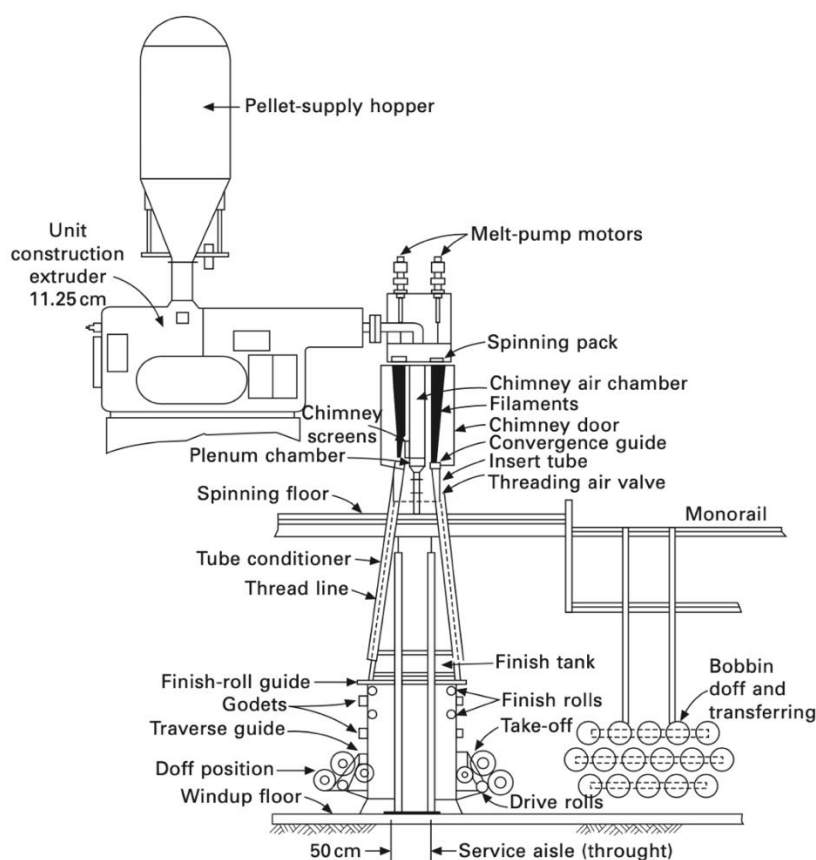
Fibers with these shapes are used for industrial applications and clothing because of their strength and shine (which can be modified, as well as their opacity, by adding titanium dioxide to the polymer before extrusion) (Richards, 2005).

2.1.2 Melt spinning process

All aliphatic (open-chain) polyamides are thermoplastic polymers, so they are sufficiently stable in the molten state, and their melting viscosities are relatively low. For polyamides, the melt spinning process is the preferred and technologically appropriate method for their production, as it is economical and more sustainable (Horrocks; Anand, 2000).

The melt spinning process for manufacturing textile fibers is shown schematically in Figure 3. The polymer is prepared to achieve the desired viscosity, to which opacifiers, pigments, antistatic agents, and stabilizers against heat and light degradation are added (Richards, 2005).

Figure 3 - Melting diagram in the polyamide yarn manufacturing process



Source: (Bunsell, 2009).

Melting temperature in the extruder should be 285-300°C for polyamide 6.6. Retention time or resistance time of the molten polymer should be long enough at the temperature mentioned above so that the molten mass is homogeneous and transparent (Horrocks; Anand, 2000).

After passing through the filter to remove large polymer particles, small gel particles and other small materials, the polymer enters the extruder. Sand packs, metal plates and nonwoven structures are commonly used as filter media (Bunsell, 2009). The molten polymer is extruded through the die, which has several small holes (about 200-400 µm in diameter). The holes are usually circular, but can have other shapes such as trilobal (**Figure 2**).

The molten polymer, after extrusion, emerges into an environment below its solidification temperature, forming filaments that are wound onto a roll moving at a linear

speed significantly higher than the extrusion speed. The take-up speed is typically over 3,000 m/min, while the average linear speed through the die is typically two orders of magnitude lower (Sacchi, 2016) (**Figure 3**).

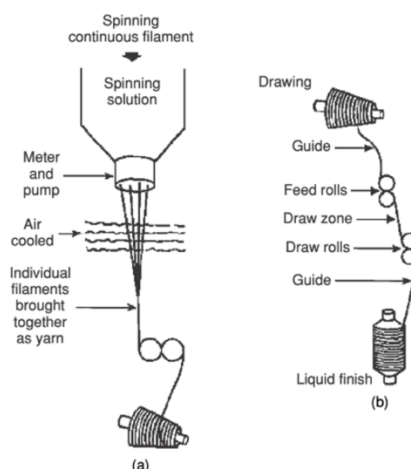
It is important to note that both fiber manufacturing and polymerization benefit from uninterrupted production periods. However, fully dedicated systems lack flexibility. A stoppage in fiber production for any reason means that polymerization must also stop. The molten polymer cannot be kept in the reactors, as it degrades. For this reason, some production chains still prefer to separate the polymerization process from the spinning process, converting the newly formed polymer into small pieces (pellets or chips) that can be stored until needed, then remelting them (Richards, 2005).

2.1.3 Fiber stretching process

When polyamide filaments leave the spinneret, they are largely amorphous (molecularly dispersed), which means that they are not yet adequately crystallized (molecularly aligned), which means their molecules are not sufficiently oriented. Thus, they must be stretched as much as necessary to develop beneficial properties, allowing them to be used in various applications, notably textiles (Bunsell, 2009).

The filament is formed by extrusion through the spinneret and passes through a set of feed rolls. It then advances to the draw rolls, which rotate at a faster rate than the feed rolls. For end uses in clothing and carpets, polyamide yarns are cold-drawn (their diameter is reduced), while for high tenacity industrial applications, the yarns are heated before drawing (McIntyre, 2005) (**Figure 4**).

Figure 4 – Polyamide fiber stretching process



Source: (Horrocks, Anand, 2000)

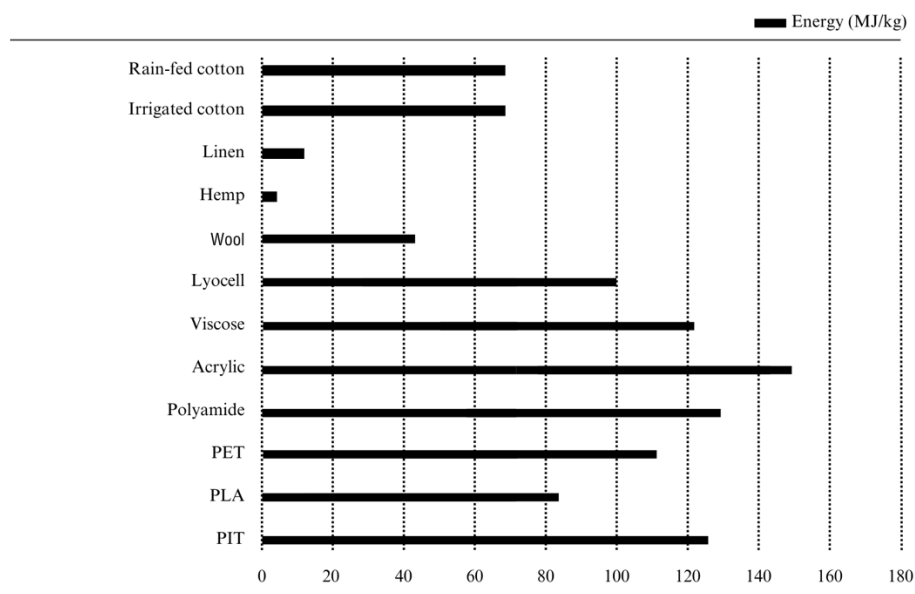
The drawing of spun fiber is performed by stretching the filament between 200 and 500% of its original length. In principle, the filaments pass through a set of feed rolls at a certain speed and are then pulled through another set of rolls (usually called draw rolls) at a speed between two and five times greater than the speed of the feed rolls. The surface speed between the draw rolls and the feed rolls is called the “draw ratio.” The stretching process facilitates the orientation of the chain molecules and improves the fiber crystallization process (Bunsell, 2009).

2.2 Sustainable aspects of polyamide 6.6

Polyamide can be considered to have some similarities to polyester, as it is also petrochemical-based, thermoplastic, and affected by the same ecological and pollution problems associated with carbon chemistry. Its manufacturing process is known to consume a significant amount of energy: producing 1 kg of polyamide requires 150 MJ, or approximately 41.667 kWh (compared to 109 MJ – or 30.278 kWh – per kg for polyester) (Figure 5). Its production process also emits nitrous oxide, a potent greenhouse gas (Fletcher, 2008).

In **Figure 5**, you can see the difference in energy consumption in the production of polyamide compared to other fibers.

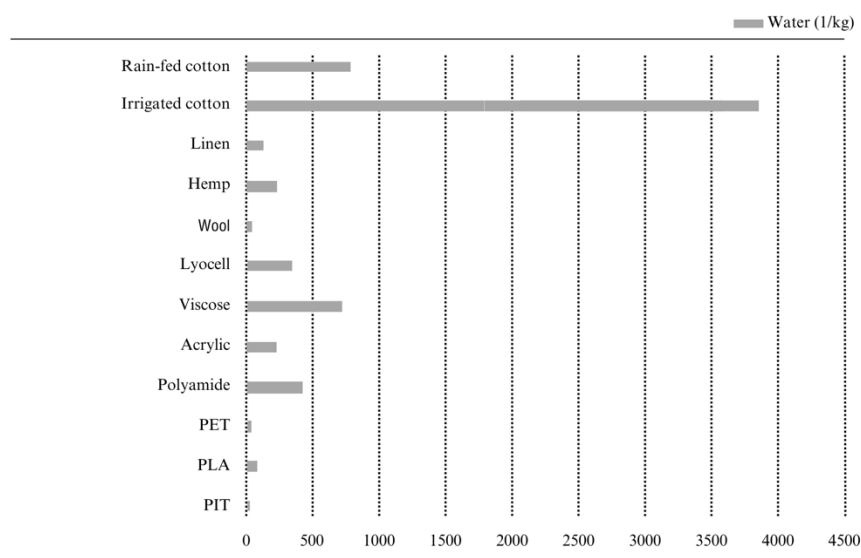
Figure 5 - Energy (MJ/kg) consumed in the production of various textile fibers



Source: Adapted from (Fletcher; Grose, 2011)

On the other hand, synthetic fibers derived from petroleum, such as **polyamide, acrylic, and polyester (PET)**, require low water consumption but high energy expenditure—above 100 MJ/kg, as shown in **Figure 6**.

Figure 6 – Water use in the production of various textile fibers



Source: Adapted from (Fletcher; Grose, 2011)

Figure 6 compares the amount of water used to produce polyamide fiber with that of other fibers. Polyamide is not among the fibers that use the most water in their

production. It consumes less water in its production than fibers such as cotton, hemp, viscose, and lyocell.

Furthermore, as shown in Figure 6, irrigated cotton exhibits the highest water consumption among all the fibers analyzed, with consumption exceeding 4,000 L/kg. This highlights the unsustainability of its cultivation under intensive irrigation systems. In contrast, rain-fed cotton performs significantly better, with less than 1,000 L/kg of water, indicating that agricultural practices adapted to the local climate can substantially reduce water impacts. However, according to the data presented in Figure 5, both types of cotton exhibit high energy consumption, at approximately 100 MJ/kg, which reveals a significant environmental impact in this regard as well.

Additionally, according to the data shown in Figures 5 and 6, hemp and flax stand out among plant fibers. Hemp has low water and energy consumption, making it one of the most sustainable options. Linen, although with slightly higher energy consumption than hemp, still maintains reasonable water efficiency rates. Wool, a fiber of animal origin, despite its low water requirements, has relatively high energy consumption. Artificial fibers show contrasting behavior. Viscose, derived from cellulose, has high water consumption—even exceeding that of rain-fed cotton—and high energy consumption, making it less advantageous from a sustainability standpoint. On the other hand, lyocell, also a cellulose-based material, has better water and energy performance, making it a more sustainable alternative within this category.

2.3 Biodegradable polyamide 6.6

The information described below was obtained during technical visits to Rhodia (Santo André, SP, Brazil), from documents provided by the company in its institutional materials, and from interviews conducted in August and November 2024 with company employees, as well as research conducted on the company's website (<https://www.solvay.com/pt-br/brazil>). The company did not provide images of internal production, nor any specific data related to the biodegradability properties of the fabric. Rhodia, a member of the Solvay group, produces biodegradable polyamide 6.6. It began to be distributed and manufactured in Brazil in 2014 (Solvay, 2024).

According to Fulgar (2024), a distributor in Italy, it has been demonstrated in

the laboratory, by the ASTM D5511 (2018) standard – “Anaerobic biodegradation of plastic materials,” that the yarn decomposes in approximately 5 years when discarded in a landfill, compared to approximately 50 years for synthetic fabrics in general, in addition to retaining up to 90% of the microplastics released into the water during the washing of items made with textiles consisting of this polyamide. Production follows a closed cycle that collects and recycles waste, wasted water, and raw materials (also found in water), and reuses heat generated during certain stages of production. This ensures that sustainable standards are maintained throughout the industrial cycle (Solvay, 2024).

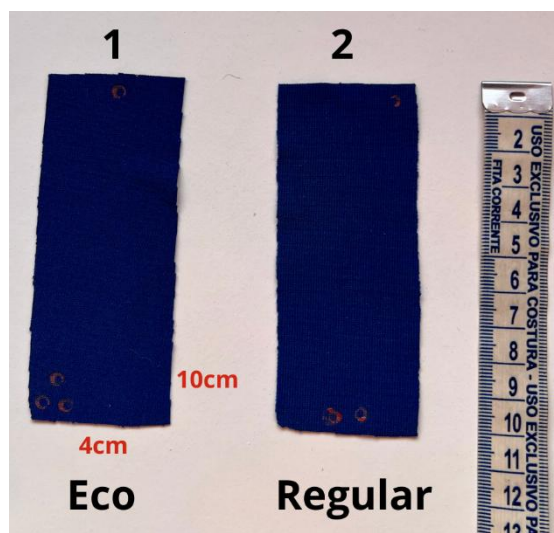
Called SoulEco by the company, it is the best seller in Europe. According to what was said during the interviews, this is because consumers in Brazil do not yet value sustainable products as much as those in Europe, where the primary customer is France. Outside Europe, the leading buyer is the United States.

3. Materials and Methods

Rhodia supplied EcoBio (biodegradable polyamide) and PA 6.6 (regular polyamide) yarns, both 2x80F68. Regarding the yarn nomenclature, it is essential to note that the “2 times” located before the yarn name 80F68 means that during the texturizing process, two 80F68 yarns are joined and twisted together. Thus, the resulting yarn is a textured yarn, consisting of two “cables” (the name given to each of the two yarns twisted together), with a total count of around 160 dtex (80 dtex per cable) and 136 filaments (68 filaments per cable). It should be noted that 160 dtex means that 10,000 meters of yarn weigh 160g.

To conduct the tests, Rhodia also manufactured four tubular pieces on a Santoni SM8-8 TOP circular knitting machine, featuring 1162 needles and a 13-inch cylinder, with a gauge of 28 needles per inch. The first piece was made using EcoBio (biodegradable) yarn, and the second piece was made using PA 6.6 yarn (regular), both yarns with 2x80F68 specifications (as explained in the previous paragraph). Two other tubular pieces (one made of regular polyamide 6.6 and the other made of biodegradable EcoBio polyamide 6.6) were left undyed (white). Two other tubular pieces (one made of regular polyamide 6.6 and the other made of biodegradable EcoBio polyamide 6.6) were also dyed by Rhodia with Nylosan Navy Blue N-RBL dye (Figure 7).

Figure 7 – Knitted fabrics dyed with Nylosan Navy Blue N-RBL: (1) EcoBio biodegradable polyamide 6.6; (2) regular polyamide 6.6. Source: Authors.”



Source: Authors.

3.1 Tensile strength, toughness, and breaking load

To test the tensile strength, tenacity, and breaking load properties of polyamide yarns, regular polyamide 6.6 yarns and biodegradable polyamide 6.6 yarns were used in an Instron dynamometer in accordance with ISO 5079 (2020) and ASTM D5034 (2021) - Standard test method for tensile strength of textile fibers. The tests were performed at Rhodia's laboratory in Santo André. Equation 1 was used to calculate the tenacity values.

Equation 1 – Toughness Calculation

$$\gamma = \frac{F}{T}$$

Where:

γ =Tenacity (cN/tex)

F= Breaking Load (cN)

T=Title (tex)

Source: Adapted from (Pinheiro, 2021)

3.2 Weight

ABNT NBR 1059 (2008) – Determination of weight on textile surfaces was used to ascertain the weight. Five test specimens of equal size were cut (**Figure 7**) and conditioned. The minimum conditioning period was 48 hours at 20 °C. After conditioning,

the test specimens were weighed on a 4-digit analytical balance (Sartorius model ED124S, Germany), and their individual weights were calculated (Cesa, 2017).

3.3 Regain

The method used to determine regain was adapted from ISO/TR 6741-4 (1987). The percentage moisture regain is defined as the percentage of the weight of the material (after conditioning at 20°C and 65% relative humidity) minus the dry weight, divided by the dry weight (**Equation 2**). Five samples of each polyamide 6.6 fabric (regular and biodegradable) were analyzed and weighed on an analytical balance (Sartorius, model ED124S, Germany). Drying was performed in an oven with forced air circulation (Binder FD Model 115, Germany) at 70°C for 24 hours or more until a constant weight was reached. The sample was then weighed again. Five repetitions were performed (Pennas et al., 2020). Regain was calculated according to **Equation 2**.

Equation 2 – Regain Calculation

$$\text{Regain} = \frac{\text{original weight} - \text{dry weight}}{\text{dry weight}} \cdot 100$$

Source: (Pennas et al., 2020)

3.4 FTIR with ATR

To perform the FTIR test with ATR (Fourier Transform Infrared Spectroscopy with Attenuated Total Reflectance), Thermo equipment (model Avatar 370 FTIR) was used with an attenuated total reflectance (ATR)/Germanium (Ge) cell (Nicolet, USA). Data acquisition was performed using Omnic software, version 4.1, 2011.19 (Monteiro, 2016). A total of seven samples were analyzed, one for each type of polyamide fabric (**see Table 3**). The standard used was ASTM E1252 (2021) – General Techniques for Obtaining Infrared Spectra for Qualitative Analysis (Monteiro; Leonardi; Savastano Jr.; Baruque-Ramos, 2016).

4. Findings

4.1 Tensile strength, toughness, and breaking load

For the tensile strength, toughness, breaking strength, and fiber elongation tests, the following results were obtained, as shown in **Table 2**.

Table 2 - Title, elongation at break, and toughness of polyamide 6.6 and biodegradable EcoBio polyamide 6.6 yarns (described in terms of mean and standard deviation)

Parameters	Polyamide 6.6 yarn 2x80F68	Eco-Bio Biodegradable Polyamide 6.6 Yarn 2x80F68
Title	163 ± 4 dtex	165 ± 4 dtex
Elongation at break	30 ± 4 %	30 ± 4 %
Tenacity	3,5 cN/dtex (≥ 3,0)	3,5 cN/dtex (≥ 3,0)

Source: Authors.

The results in Table 2 indicate that the data are consistent with those in the literature for regular polyamide 6.6 (Table 1). However, no statistically significant differences were observed between the two types of yarns analyzed using Student's t-test at a 5% significance level.

4.2 Weight

The results (expressed in terms of mean and standard deviation) were 343±4 g/m² for regular polyamide 6.6 and a mean of 338±2 g/m² for biodegradable polyamide 6.6 (EcoBio). Thus, no statistically significant difference was observed between the two values obtained. Although weight is not directly associated with differences in the properties of the two materials, it demonstrates that the two knitted fabrics were produced in the most similar manner possible, ensuring that their construction would not interfere with any other test results.

4.3 Regain

The results obtained with regain were an average of 4.82% (standard deviation of 0.06%) for regular polyamide and an average of 4.87% (standard deviation of 0.07%)

for biodegradable polyamide. These values do not show a significant difference in regain between the two polyamide 6.6 fabrics: regular and biodegradable (EcoBio).

4.4 FTIR with ATR

The captions for the different samples analyzed in FTIR with ATR from 4000 to 500 cm^{-1} in Thermo equipment (model Avatar 370 FT-IR), using the ATR/germanium cell (Nicolet, USA), are shown in **Table 3**.

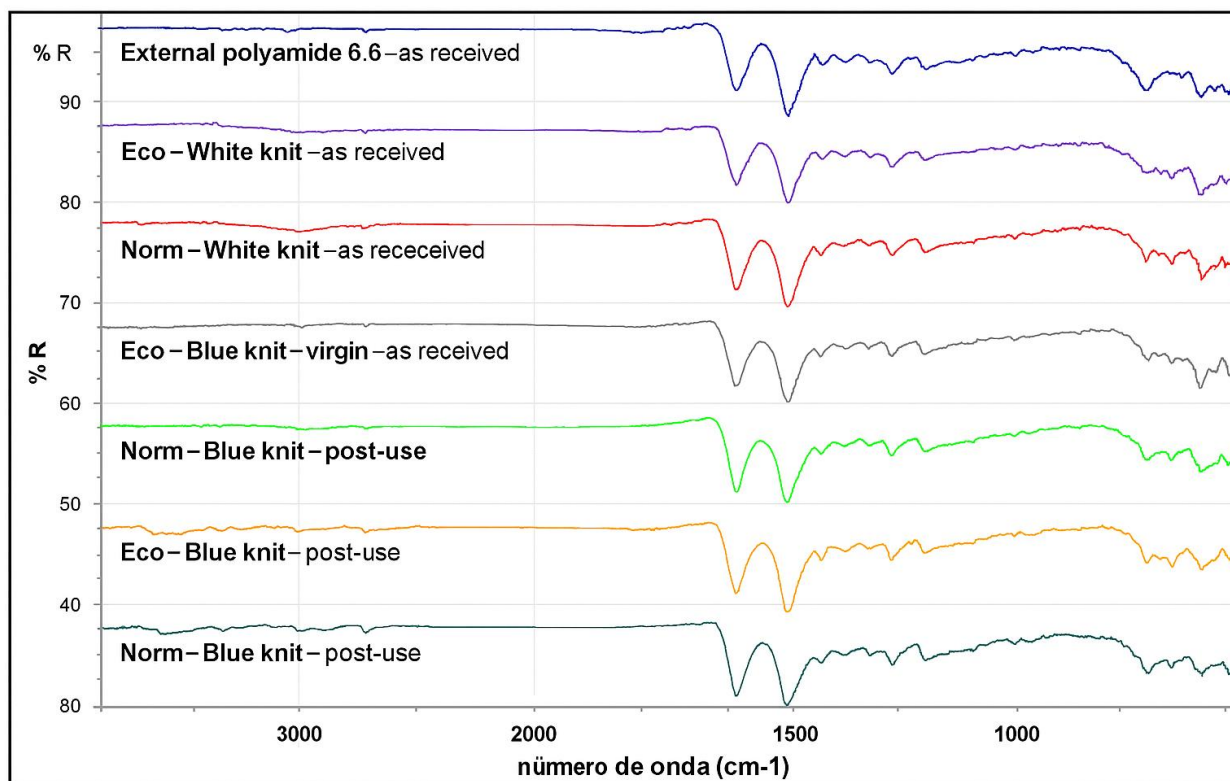
Table 3 - Legend for the polyamide samples used in the ATR-FTIR test application.

<i>Samples (Polyamide 6.6)</i>	<i>Names used in the analysis</i>
External polyamide 6.6 – as received	External polyamide 6.6 – as received
Biodegradable polyamide 6.6, unused, white	Eco – White knit – as received
Regular polyamide 6.6, unused, white	Norm – White knit – as received
Biodegradable polyamide 6.6, unused, blue	Eco – Blue knit – virgin – as received
Regular polyamide 6.6, unused, blue	Norm – Blue knit – virgin – as received
Biodegradable polyamide 6.6, post-use, blue	Eco – Blue knit – post-use
Regular polyamide 6.6, post-use, blue	Norm – Blue knit – post-use

Source: Own authorship.

The spectra of the samples (Figure 8) were similar, with no significant changes in any of the tests, indicating a very similar molecular composition among them, including the biodegradable samples. Although it is not known whether there is a specific additive that leads to biodegradability, the results lead to the hypothesis that the compound or element used to make the fabric biodegrade more easily (in the case of biodegradable polyamide 6.6) is inside the fiber and not on the outside, and that it is in a concentration that this methodology cannot detect.

Figure 8 – ATR-FTIR of polyamide 6.6 samples as described in Table 3.



Source: Own authorship

Finally, although no biodegradability tests have been performed for the materials mentioned in Table 3 and Figure 8, it should be noted that polyamide is tested for biodegradation under conditions defined by the following standards: (i) ASTM D5511 (2018) - Standard Test Method for the Determination of Anaerobic Biodegradation of Plastics Under High-solids Anaerobic Digestion Conditions (equivalent to ISO 15985 (2014)); and (ii) ASTM D6691 (2025) - Aerobic Biodegradation of Plastic Materials in Marine Environment (Solvay, 2025).

ASTM D5511 (2018) is the most widely used standard for assessing the anaerobic biodegradability of plastic materials. The method primarily involves using a laboratory digester. The sample is exposed to an inoculum obtained from an anaerobic digester containing a high concentration of methanogenic microorganisms. The volumes of methane and carbon dioxide produced by the biodegradation process are measured accurately. By comparing these volumes to the theoretical volume based on the carbon content of the material, the percentage of biodegradation over time can be calculated.

This method reproduces conditions similar to those found in biologically active landfills (Solvay, 2025).

ASTM D6691 (2025) is the most widely used standard for assessing the aerobic biodegradability of plastic materials in a marine environment. The method, which simulates conditions found in marine environments, involves exposing the sample to an inoculum of various isolated marine microorganisms or a sample of natural seawater containing inorganic nutrients. A respirometer is used to measure the total biogas (carbon dioxide) produced over time. By comparing the volume of carbon dioxide produced by the biodegradation process with the theoretical volume, based on the carbon content of the material, the percentage of biodegradation over time is calculated (Solvay, 2025).

5 Final Thoughts and Conclusion

The objective of this study was to compare the properties of regular polyamide 6.6 and biodegradable polyamide 6.6. To this end, laboratory tests were conducted on yarns and knitted fabrics produced with these two materials, in addition to collecting data from professionals in the field.

The results obtained showed that, under the tested conditions, no significant differences were observed between the two types of polyamide in terms of technical performance and physical-chemical properties. Both exhibited similar behavior during the tests performed, with no functional superiority of one over the other. Despite this, it is worth noting that the primary distinction between the fibers lies in their post-disposal environmental behavior, as the biodegradable version is designed to decompose more quickly under specific landfill conditions. However, this characteristic could not be verified within the scope of this study, as no biodegradation tests were performed.

From an industrial perspective, the use of biodegradable polyamide 6.6 may represent a promising approach to sustainability, particularly in production chains committed to minimizing environmental impacts. However, the absence of significant technical differences between the fibers reinforces the importance of critically evaluating the discourse of sustainable innovation, considering the complete life cycle of materials, disposal contexts, and possible implications for the end consumer.

A limitation of this study is that the analyses were not performed in controlled degradation environments. It is therefore recommended that future research further investigate biodegradation in different environmental scenarios, as well as conduct broader investigations into the impact of these fibers on recycling flows, production, and reverse logistics.

In summary, although biodegradable polyamide 6.6 did not show any measurable technical differences from regular polyamide 6.6 in this study, its environmental potential remains a relevant area of research and development for the contemporary textile industry⁴.

⁴ Grammatical revision by Fernanda Gonçalves de Carvalho, B.A. in Portuguese-English Language and Literature from the University of São Paulo (USP), 2012. Lattes: <http://lattes.cnpq.br/7076801901634811>. E-mail: fgcrevisao@gmail.com.

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Declaration of Contributions by Authors and Collaborators (CRediT - Contributor Roles Taxonomy)

Authors Júlia Escobosa, Julia Baruque, and João Marcicano conceived and planned the study; designed the methodology and performed data collection and analysis; and participated in the writing and final revision of the manuscript. All authors approved the final version of the abstract.

Supplementary Materials

All data necessary to reproduce the results are contained in the article itself.

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