

Tannins and Leather: Chemistry, Tanning Processes, and Environmental Impacts

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ABSTRACT

Tannins are plant-derived polyphenolic compounds that stabilise collagen fibres and give the finished product qualities like strength, flexibility, and water resistance. Leather manufacturers frequently use tannins for this reason. This article covers the intricacy of tannin molecules, their applications in the leather production sector, and their roles in collagen cross-linking, water repellency, and the mechanical properties of leather. It also discusses the more traditional tanning techniques, such as chromium and vegetable tanning, emphasising their differences and potential environmental consequences. The review study collects a wealth of information on tannins and the tanning process, analyzes what is already known, and assesses innovation and its impact on the environment. There are other steps to reduce these effects, such as the use of laws and environmentally friendly practices. We discuss the allure of tanned leather in furniture, cars, and fashion, along with laws and regulations that emphasise environmentally friendly manufacture.

Keywords: Tannin, Leather production, Polyphenolic compounds, Sustainable Practice, Environmental impact

INTRODUCTION

Leather is one of the oldest materials still valued today due to its strength and flexibility. The tannins in leather play a major role in its transformation from animal skin to a desirable product. Tannins are a broad category of polyphenolic compounds found in a variety of plants[1]. Tannins are vital to the leather process, which combines chemistry and art to produce the desired quality and character of leather[2]. The intricate chemistry of tannins lies at the basis of this method, which dates back to the 18th century. These compounds give leather its strength, pliability, and resistance to putrefaction. They are also well-known for their capacity to cause protein coagulation and interact with collagen fibres in animal skins. Tannins achieve this through a process known as tanning, which bonds the collagen to the hide and turns it into a durable substance that is difficult to break down. Because of the variations in their structures and how they interact with proteins, tannins have diverse chemical characteristics. We typically divide these natural substances into two major groups of tannins namely condensed tannins and hydrolyzable tannins[3]. Gallotannins and ellagitannins are hydrolyzable from oak and chestnut, whereas condensed tannins, or proanthocyanidins, come from quebracho and mimosa[4]. The tanning process generates characteristics of the leather-based on the benefits associated with each type of tannin. The tanning industry has a long history, but it continues to grow thanks to new technological advancements. In the past, the common process to give leather its distinctive rich color and finish was vegetable tanning, which extracts tannins from plant materials. On the other hand, early in the 20th century, chromium tanning gained popularity as a new tanning technique due to its effectiveness in speeding up manufacturing and producing softer leather. However, because of its toxicity and ecological impacts, the use of chromium in tanning operations has increased environmental repercussions. However, we must acknowledge that discussions about the environmental impact of leather production still require significant attention. Because the chemicals used in tanning produce water tainted with compounds like chromium, it is important to dispose of the waste properly because the chemicals employed are

harmful. To address these issues, advances in ecologically friendly tanning methods, including vegetable tanning and natural tannin sources, have been made, as has research into other tanning chemicals. In addition to being a material for industry, leather is valued for its high level of workmanship and craftsmanship and has global social and economic significance[5]. Due to its adaptability and timeless style, leather is still in demand in fashion companies, the automotive industry, and the furniture industry. During this tour, we talk about the several chemical processes involved in tanning, the environmental effects of leather manufacturing, and current efforts to produce leather sustainably through tannins and leather. With this investigation into the connections between tannins, leather manufacturing techniques, and the outside environment, we hope to shed some light on the issues and possibilities that will shape this age-old industry going forward. From here, we can observe the cultural values and prospects for resource sustainability in the context of globalisation, in addition to the scientific and industrial aspects of tannin and leather.

Chemistry of Tannin

Plant tissues contain large quantities of polyphenolic chemicals called tannins, which can precipitate proteins. Hydrolysed and condensed tannins, also known as proanthocyanidin, and hydrolyzable tannins are the two basic types into which they fall [6].

Types of Tannin

a. **Hydrolyzable Tannins:** These tannins originate from the esters of gallic or ellagic acid, which are present in glucose and other carbohydrates[7]. These tannins are mostly found in tara, chestnut, and oak plants. We can divide them into two subclasses: ellagitannins, which obtain their tannin from ellagic acid, and gallotannins, which obtain their tannin from gallic acid. Exposure to acids or enzymes modifies hydrolyzable tannins, causing them to break down and release either gallic acid or ellagic acid.

b. **Condensed Tannins (Proanthocyanidins):** These tannins consist of oligomers or polymers of flavan-3-ols, specifically epicatechins and catechins[8]. The usual sources of this tannin include grape seeds, quebracho, and mimosa. Monomers of flavan-3-ol condense and undergo a polymerization process to create them. Condensed tannins, which are water-soluble and capable of forming interactions with proteins, give meals and drinks an apparent astringent quality.

Chemical Interactions

- i. Tannin attaches itself to proteins through hydrophobic and hydrogen bonding interactions, forming complexes and precipitating them[9].
- ii. The tanning process uses these interactions to harden the collagen fibers in animal skins, generating leather.

Applications

- i. In addition to tanning leather, the food and beverage sectors employ tannins as astringent agents.
- ii. Conventional medicine also utilises tannins due to their anti-inflammatory and antioxidant properties[10].

Tanning Processes

Tanning is the process of applying tanning compounds to raw animal hides to turn them into leather. There are several main types of tanning processes which include:

Vegetable Tanning Process

The method of employing tannin obtained from plants, such as the bark, leaves, or fruits, is known as vegetable tanning[11]. Tannin strengthens and increases the hide's suppleness by filling in the voids left by collagen fibers. As a result, the leather is not soft but rather dense, and substantial, and it develops a lovely patina with age. High-end leather goods such as saddlery, belts, and leather objects extensively utilize this leather.

Chrome Tanning Process

Chromium salts, particularly chromium sulfate, are the tanning agents of this process. In this case, chromium ions can interact with the collagen fibres more effectively than vegetable tannins, resulting in leather that is more pliable and supple[12]. This results in a more uniform color, greater water resistance, and a quicker tanning period when compared to vegetable tanning. Shoes, car interiors, and upholstery are among the products that frequently use chrome tanning.

Other Tanning Methods

Aldehyde Tanning: Aldehyde tanning typically involves the use of aldehydes such as glutaraldehyde to cross-link collagen fibres.

Synthetic Tanning Agents: These includes a variety of artificial materials, including polymeric resins and phenols.

Combined Tanning Procedures: Certain tanneries use different tanning techniques to extract specific properties from leather.

Regarding the final leather product's quality, durability, and environmental impact, each of the tanning methods under discussion has special qualities of its own. Tanners prefer one tanning technique over another for a variety

of reasons, such as the type of leather required, tanning effectiveness, and environmental effects. The current research's goal is to reduce the number of chemicals and emissions used in the tanning process, while also developing more environmentally friendly tanning methods.

Role of Tannins in Leather Production

Thus, tannin plays a crucial role in leather production, transforming raw animal hides into usable leather. Their primary functions and contributions include:

Collagen Stabilization

Tannins react with the collagen fibres found in animal skins.

This binding interweaves and solidifies the collagen structure that gives the leather its strength and suppleness. -

Water Resistance

Because tannins cover the voids between the collagen fibres, they aid in making the leather waterproof[13].

Because of this water resistance characteristic, leather is less prone to water damage and is less susceptible to it.

Improvement of Physical Properties

Tannins fortify the leather's tensile strength and tear resistance, thereby improving the mechanical properties of the final product[14].

Depending on the kind and quantity of tannins employed, they impact the leather's strength, compactness, and thickness.

Aesthetic and Functional Characteristics

Vegetable and chrome tannins are the two main types; each gives leather a unique patina, appearance, and feel.

Over time, they impede the formation of the natural layer on the surface of leather, which is prized in high-quality leather goods.

Environmental Impacts of Tanning

Tanning, which is fundamental in leather manufacturing, has significant environmental implications, particularly in terms of the chemicals used and the effluent. Key environmental impacts include:

Chemical Pollution

Chromium tanning, the most generally used process, requires chromium salts (chromium sulfate).

If not effectively controlled, chromium is detrimental to the environment and will pollute soils and water sources[15].

Wastewater Contamination

Tanning processes produce considerable quantities of wastewater with chromium, other compounds, and organic materials.

Improperly handled raw sewage or wastewater can contaminate water supplies and other types of land, harming both the ecosystem and human life.

Energy Consumption

The production of leather necessitates extensive heating and drying procedures, which consume a significant amount of energy[16].

High energy intensity hurts the environment because it causes greenhouse gas emissions.

Deforestation and Land Use

Plants and trees provide tannins for vegetable tanning.

Harvesting done incorrectly can deplete the remaining wood, resulting in species extinction and community space loss.

Efforts to Mitigate These Environmental Impacts of Tanning

Adoption of Eco-Friendly Practices: For instance, using natural tanning agents like vegetable tannins and utilising new technologies to minimise the utilisation of chemicals and the ensuing formation of wastewater are some of the measures taken to reduce these environmental impacts[17].

Waste Management and Treatment: Handling wastewater properly will lower pollution levels and ensure that it complies with current environmental regulations.

Standards and Certification: The Leather Working Group's certifications, along with strict environmental guidelines for sustainable supply chain procedures, are utilized[18].

Therefore, it is imperative that the leather sector consistently meet demand without endangering the environment. Through ongoing research and development, we are improving tanning techniques to reduce their harmful environmental consequences without sacrificing cost or quality.

Applications of Tanned Leather

Tanned leather is consequently in demand in various production industries due to its advantages of being durable, aesthetically pleasing, and, of course, multifunctional[19]. Key uses include:

Fashion and Apparel

In the luxury market, it is particularly prized for clothing, accessories, luggage, and shoes.

It is highly sought after for fashion-forward textiles and casual clothing because of its smooth, glossy, and natural feel.

Furniture and Upholstery

To improve the look and durability of accessories like couch sets, chairs, and ottomans, leather is applied throughout the manufacturing process.

It is adored because it is easy to use, doesn't require a lot of cleaning, and can be used every day.

Automotive Interiors

Automobiles frequently use leather for interior trimmings, steering wheels, and seats.

They raise the cars' value and luxury level by enhancing their comfort, durability, and appearance.

Other applications of Tannin leather include travel accessories, briefcases, belts, and wallets are among the products made from this material. All of these qualities support the items' long-term usefulness and durability, as well as the necessary flexibility. Decorative items such as wall panels, artwork, and book covers use leather. Its natural grain, ability to develop as a material, and organic appearance are just a few of the adaptable qualities that make it ideal for use in artistic and interior design projects. Other relevant fields use leather for gloves, safety shoes, and protective clothing and accessories. It may provide heat insulation and have a higher abrasion resistance, making it appropriate for use in abrasive environments. Architectural designers are increasingly using this material to craft accent pieces, acoustical treatments, and wall panels. Both ultramodern and traditional dwellings can utilize it due to its adaptability in texture and color. Numerous industries demonstrate the countless applications of tanned leather, reinforcing the product's resilience and adaptability. Its resilience against deterioration, adaptability, and capacity to enhance any surface has made it a favorite among producers, designers, and consumers.

Regulations and Standards in Leather Production

The leather production process incorporates safety regulations and environmental standards to maintain the manufacture of high-quality leather[20]. Another significant issue is the regulation, use, and disposal of chemicals used in the tanning process, especially chromium. To lessen the negative impact on the environment, they aim to restrict emissions of water, air, wastewater, and solid waste. Regulations govern the use of dyes, tanning agents, and other chemicals to uphold legal obligations and reasonable standards for workplace health and safety. Materials that satisfy the criteria for being hazardous to the environment or human health may be subject to limitations, which would encourage the use of less hazardous items. These consist of safety regulations and occupational health standards for those employed in tanneries and the leather processing sector. Labour standards support fair pay and other rights for workers in the leather industry, as well as balanced relationships between companies and employees. Furthermore, quality standards establish the criteria for grading leather based on its strength, durability, and appearance[21]. We can also use traceability standards to address environmental and ethical sourcing issues, as well as identify the source of raw materials. International organisations, such as the Leather Working Group (LWG), establish standards to assess the quality of leather manufacture[22]. International policies vary, and every nation has passed its laws about labour, the environment, and health. As a result, leather producers must adhere to these criteria to stay in the market, safeguard customers, and implement sustainability measures as required by regulatory agencies. In the leather value chain, the focus is on continuous improvements and modifications to processes and technologies that can support social responsibility and environmental sustainability while also meeting regulatory requirements[23].

CONCLUSION

Tannins play a crucial role in leather production due to their varied applications and intricate chemical makeup, transforming animal pelts into durable, multifunctional goods valued across a wide range of industries. However, concerns exist regarding the environmental impact of tanning processes, necessitating further advancements and adherence to laws and guidelines related to sustainable development. As the demand for leather increases and changes on a global scale, the ideas of where and how to develop without sacrificing the environment become critical to the business's sustainable future.

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CITE AS: Benedict Nnachi Alum (2024). Tannins and Leather: Chemistry, Tanning Processes, and Environmental Impacts. NEWPORT INTERNATIONAL JOURNAL OF SCIENTIFIC AND EXPERIMENTAL SCIENCES, 5(3):33-37. <https://doi.org/10.59298/NIJSES/2024/10.5.333337>