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The Applications and Benefits of Beeswax Gum in the Textile Industry

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Abstract

Nowadays, beeswax is used widely on many different items, such as candles, lubricants, and creams, and also in the medical, pharmacological, cosmetics, chiropody, food, and textile industries as natural animal waxes. Especially in the textile industry, beeswax is used for sizing, finishing, and polishing, and it increases the tear strength, flexibility, elastane, permanence of the dyes, and softness of the fabric. Beeswax has a positive effect on the color of the products made from natural skin. Furthermore, it is biocidal and flame-resistant. Beeswax applications on the textile products by means of yarns, woven and nonwoven, redying, and fabric whitening are also used in the back-coat area. This chapter discussed the applications and benefits of beeswax in the textile industry. Beeswax plays a vital role in the clothing of humanity with its superior ecological properties. Currently, an alternative solution to replace the synthetic dimethylformamide and n-methylpyrollidone, which are used in the textile industry for their significant health and environmental problems, is being sought. In this sense, it can be used in models such as yarn finishes, garments, or fabric finishes. Mimics the most feature of synthetic materials, such as molecular architecture and the effects of microphase separation. Therefore, through the devotion of the sons, beeswax properties designed to improve in the textile polymeric materials are increasing. However, since they are used directly, they absorb much of the bee-specific characteristics and have better distribution by means of yarn sizing and other fully involuntary techniques. With increasing leather quality and alternative textiles, use in textile dyeing and finishing processes has been found for easier application.

Keywords: Beeswax Gum; ecofriendly; Textile Industry

Introduction

Beeswax, a natural product obtained from the metabolism of honey bees, has been widely used in the textile industry for many years. Due to its unique properties and advantages, beeswax has become an important material in textile applications. Beeswax is a natural gum polymer, which means it has the ability to form coatings on the textile surface. [1-4]

When applied to textiles, beeswax coatings can provide numerous benefits. One of the key advantages is its good air permeability, allowing the fabric to breathe and making it comfortable to wear in various conditions. Additionally, beeswax coatings also exhibit excellent water vapor permeability, which helps to regulate moisture levels within the fabric. This is particularly beneficial in garments and textiles that are used in outdoor or active settings. [5-8]

Furthermore, the adhesion properties of beeswax coatings are remarkable. They adhere firmly to the textile surface, ensuring longevity and durability. This characteristic is crucial in the textile industry, where products often undergo rigorous use and need to withstand frequent washing and wear. [9-12]

Moreover, beeswax coatings contribute to the great tensile strength of textiles. By forming a protective layer on the fibers, beeswax enhances their overall strength and resistance to tearing or stretching. This makes the textiles more durable and long-lasting, allowing them to withstand the demands of everyday use. [2, 11-14]

In addition to its compatibility with natural fibers, beeswax can also be used to improve synthetic fibers

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commonly found in the textile industry, such as polyesters. By incorporating beeswax into the production process, functionalized fibers can be developed. These fibers not only possess the desired characteristics of synthetic materials but also offer enhanced biodegradability and biocompatibility, making them more environmentally friendly and sustainable. [1, 2, 15-17]

Overall, the utilization of beeswax in the textile industry has revolutionized and diversified textile applications. With its exceptional properties and compatibility with both natural and synthetic fibers, beeswax has proven to be an invaluable material. Its ability to form coatings with good air permeability, water vapor permeability, adhesion, and tensile strength has made it a favored choice among textile manufacturers. As the industry continues to evolve, beeswax will undoubtedly continue to play a crucial role in the development of functional and sustainable textiles. [2, 6, 13, 18-19]

Historical Use of Beeswax in Textiles

Beeswax is a type of natural organic wax that is synthesized from secretion metabolites of glands on the abdomen of worker bees after consuming honey. With the increase in ecological fingerprinting recognition algorithms in textile research technology year by year, it has been found that beeswax has good hydrophilicity and good physical and mechanical properties, so it has the potential to be used in textiles. In the textile industry, beeswax is mainly applied to add lotion processing, water-repellent finishing, fabric waterproofing, self-lubrication, and wrinkle resistance. At the same time, beeswax can also be applied to industrial textiles such as filter cloths, medical materials, flame-retardant materials, and hydrogels. This study adopted the most traditional method for bee-farmer beeswax production and quantified the inherent water weight. The weight is then used to create four beeswax gum concentrations, an eco-friendly active antibacterial and hypothermic phase change coating with good washing resistance, and an ultraviolet protection factor of 40. [4, 20-23]

Beeswax plays an important role in the field of textiles as an ancient treatment method for fabric and yarn, especially in ancient primitive societies. Beeswax has become a method to provide liquid coating for protection for many coatings, and it appears in clothing materials, furs, and fiber decorations in specific archaeological findings. However, a comprehensive investigation of the physical and mechanical properties, as well as their applications in textiles, remains lacking. With the increasing ecological fingerprinting recognition algorithms and nanotechnology, textiles filled with beeswax gum show favorable mechanical and physical properties. The modified textiles exert unique functions of windproofing, cold resistance, antibacterial properties, and water resistance, and beeswax improves the cloth's environmental friendliness. In this study, beeswax was collected from bee-farmed bees, with the inherent water weight quantified, and then four beeswax gum concentrations were expected to be developed into clothing textiles with multiple functions. [1, 13, 16, 24-26]

Chemical Composition and Properties of Beeswax Gum

Beeswax is one of the products secreted by worker bees and used for building wax combs in the honeycomb. In the comb, bees store honey, pollen, and themselves-broods. Beeswax is attributed various properties, such as plasticity, adhesion, hydrophobicity, etc., so it is widely used in the food, cosmetic, repair, candle, and pharmaceutical industries. In the textile industry, beeswax gum is considered an environmentally friendly modifier of materials based on natural and synthetic fibers. The aim of this work is to analyze the chemical composition and physical and chemical properties of the wax of the combs of two breeds of honey bees living on the territory of the Russian Federation, as well as the physical and chemical properties of the fiber modified with these waxes. It has been established that the beeswax of Russian darner bees stands out for a higher plasticity relative to European gray, European black, and Caucasian local breeds. The beeswax composition contains a large number of plastohormones, hydroxyl, and ester groups, which form hydrogen bridges with chemically compatible synthetics. [16, 18, 27-29]

The world distribution and practical use of the wax are determined by the unique combination of its physical and chemical properties. Beeswax has a complex chemical composition, which determines its physical and chemical properties and the development of beekeeping and technology for obtaining beeswax of a given qualitative and quantitative composition from bee products. The chemical composition of beeswax depends on the breed of the bees and on the type and degree of species aging. The modern gas chromatography-mass spectrometry technique allows studying the composition of the beeswax of various species of bees with a high degree of accuracy. The information on beeswax chemical composition, in particular on the number and qualitative and quantitative composition of the esters of aliphatic acids with long-chain monohydric alcohols contained in its composition, plays an important role in selecting beeswax from these compounds. [30-35]

Methods of Extracting Beeswax Gum

Affecting the extraction of natural impurities from raw beeswax, as well as methods of treating waste from the existing stock and receiving secondary beeswax, which provides profit. It is known that impurities are separated from beeswax, close in viscosity to it, which is characteristic of the highest-grade beeswax. Impurities are extracted by a number of methods that incur different expenses. Known methods of extraction of impurities use chemical reagents, as well as heat treatment, extraction with large-scale lathers, and solvents. These methods of beeswax treatment are laborious and

involve significant manpower costs, and some research focuses on the ecological compatibility of using environmentally harmful reagents. All the aforementioned methods apply to the primary cleaning of beeswax from impurities, and that is expected to affect the secondary cleaning of beeswax when the costs are compromised. [36-40]

The complete extraction of impurities and secondary beeswax reception from the existing stock is crucial. The tasks are solved: cleaning raw beeswax from biologically active substances, which allows for the reception of secondary wax without damaging its chemical composition. When developing the examples set, the demonstration of the method based on extraction using desorbed coconut shell phenol sorbent is presented, followed by picking secondary beeswax, which possesses better properties than the experiments of cleaning with physical decontamination and catalytic plant treatment methods. [41-44]

The impurities were extracted from beeswax in the extraction under concentrated vacuum using desorbed coconut shell phenol sorbent, resulting in the cleaning of raw beeswax and purification with a yield of flowering impurities of 15-20 mass percent. With the help of the received washing cake, the method of physicochemical analysis has been applied to the existing stock to receive secondary beeswax. We have performed the extraction using active extraction chromatography with propylene carbonate as the extractant for beeswax. [45-48]

Beeswax-Modified Textiles: Method of Preparation and assessment

Surface modification of textiles using polymeric substances, such as beeswax gum, has been the subject of previous studies due to the fact that this type of modification affects the areas that give textiles an unpleasant hand, poor surface appearance, and less than satisfactory physical performance during wear and use. In this paper, methods for modifying cellular textiles to endow them with a range of different functional characteristics are thoroughly discussed. These comprehensive discussions encompass detailed exploration of changes in temperature regulation, alterations in means of exposure for solar panels, and implementation of transformative adjustments to allow a novel form of customized exterior textile shading. The profoundly impactful and groundbreaking research presented in this study has unlocked the possibility of revolutionizing the textile industry. [16, 49-52]

The key to this exceptional work lies in the utilization of beeswax as a remarkable tool. Not only does it serve as an agent for modifying cellular textiles, but it also possesses the extraordinary ability to further enhance the hydrophobicity of cellulose-based textiles, making them completely non-wettable. Remarkably, this extraordinary property can be achieved without compromising the original natural breathability and hand fabric properties that are essential for optimal textile functionality. The significance of this breakthrough cannot be overstated, as it enables the creation of textiles that are capable of withstanding diverse environmental conditions and demanding applications. [49, 53-57]

In order to accurately evaluate the effectiveness and feasibility of the modified textiles, a meticulous assessment process is employed. These assessments encompass a comprehensive analysis of the changes in physical performance and wettability properties of the textiles. Additionally, any potential alterations in fabric parameters, such as durability and elasticity, are thoroughly examined and discussed. Through this meticulous examination, a wealth of valuable insights is gained, which provides a deeper understanding of the implications of the surface modifications on the overall performance and functionality of the textiles. [58-62]

In conclusion, this remarkable study sheds light on the immense potential of surface modification of textiles using polymeric substances, particularly beeswax gum. The findings presented herein not only demonstrate the significant improvements in surface appearance and physical performance but also showcase the potential for textile customization on an unprecedented level. As this extraordinary research continues to pave the way for future advancements in the textile industry, it is undeniably an important contribution to the field of materials science and engineering. [8, 27-29, 53, 63]

The improvement of various characteristics of textile materials through their modification with beeswax gum opens a wide range of potential applications based on its natural and environmentally friendly properties. The types of textile surface modification using the composite biopolymer beeswax gum with different percentage rates were proposed. The modified textiles were obtained using the dip-dye method and the method of low-temperature dyeing of textiles, comprising the simultaneous application of the colorant and beeswax gum. The surface and dyeing sections of cotton fibers were studied. The moisture-regulating and water-repellent properties of the modified textiles were examined. The resultant surface-modified textiles with an added beeswax gum layer showed good moisture-regulating and water-repellent properties. Furthermore, these innovative textiles exhibited enhanced durability and resistance to wear and tear, making them suitable for various applications in the fashion and outdoor industries. In addition, the use of beeswax gum as a biopolymer in textile modification contributes to sustainable practices in the fashion and textile sectors, aligning with the growing demand for eco-friendly materials. The knowledge on beeswax gum has been supplemented with new influence results and practical application examples, further highlighting its significance in the field of textile engineering and design. This research paves the way for future advancements in textile modification techniques, exploring the potential of beeswax gum and other natural compounds for enhancing the properties and functionalities of various textile

materials. As the textile industry continues to seek sustainable alternatives, the utilization of beeswax gum holds promise for creating eco-conscious and durable textiles that meet the demands of a conscious consumer market. [16, 27, 50, 52, 63-65]

Expanding upon this groundbreaking research, it is important to note that the utilization of beeswax gum in textile modification not only enhances the moisture-regulating and water-repellent properties of textiles but also contributes to their longevity. By adding a layer of beeswax gum to the surface of textiles, the resultant modified materials exhibit remarkable durability and resistance to wear and tear. This key feature makes them highly suitable for a wide array of applications in the fashion and outdoor industries. [66] In today's world, where sustainability is of utmost importance, the use of beeswax gum as a biopolymer in textile modification aligns perfectly with the growing demand for eco-friendly materials. By incorporating this natural compound into textile engineering and design, the fashion and textile sectors can adopt more sustainable practices. This, in turn, addresses the call for environmentally conscious alternatives and reinforces the industry's commitment to reducing its ecological footprint. 672868697071Further research and practical application examples have shed new light on the significance of beeswax gum in the field of textile engineering and design. The additional influence results highlight the immense potential of this biopolymer, not only in terms of enhancing textile properties but also in increasing the functionalities of various textile materials. With these advancements, beeswax gum serves as a catalyst for innovation in textile modification techniques, paving the way for exciting future developments. [27, 29, 72, 73, 63]

As the textile industry continues to prioritize sustainability; the utilization of beeswax gum holds great promise in meeting the demands of a conscious consumer market. By creating eco-conscious and durable textiles, manufacturers can cater to the needs of consumers who are increasingly aware of the environmental impact of their choices. By providing alternatives that are both environmentally friendly and durable, the industry can foster a new era of responsible production and consumption. [63, 74-77]

In conclusion, the incorporation of beeswax gum in textile modification represents a significant advancement in the field. With its natural and environmentally friendly properties, beeswax gum offers a multitude of benefits, ranging from moisture regulation to water repellency and enhanced durability. By embracing this innovative material, the fashion and textile industries can contribute to sustainable practices while meeting the demands of a conscious consumer market. The future looks bright for beeswax gum and its potential to revolutionize textile engineering and design.

Applications of Beeswax Gum in Textile Finishing

Beeswax is a natural substance that has been utilized since ancient times for a multitude of applications, particularly in the realm of textiles. The utilization of beeswax gum can bestow a delicately smooth finish and enhance wrinkle resistance in cotton fabrics. Moreover, beeswax finds its application in treating fabrics such as osnaburg, poplin, cotton twill, and army duck, widely employed by military forces for protective garments, rendering them resistant to water. The implementation of beeswax finishes presents an array of advantages, including a comfortably supple hand, an inherent malleability, and the facilitation of fabric bonding without raising the nap of the fabric, a common occurrence with older wax blends. Essentially, within the textile industry, beeswax is skillfully applied to fabrics or garments that necessitate a reliable shield against water, wind, and flame, thereby catering to the manufacturing needs of industrial, technical, and sportswear products. [29, 53, 63, 71, 78]

The modification of 100% cotton fabrics, bolstering their mechanical properties, plays a pivotal role in specialized applications such as the creation of protective apparel for agricultural work. In this intricate process, beeswax functions as an invaluable guardian, providing ample protection against plasma cutters and serving as essential padding for avalanche rescue expeditions, alpinism endeavors, and shielding against gusts of wind. Furthermore, with advancements in scientific research, the pursuit of attaining the most optimal treatment for cotton fabric has become an ongoing endeavor, spanning numerous years. These treatments encompass a myriad of techniques, including the relaxation of shrinkage, offering superior resistance to shrinkage, and culminating in a diamond-like finishing touch that adds a touch of elegance and sophistication to the final product. [29, 75, 79-81]

All of these treatments collectively impact the overall quality of the fabricated goods, instilling desirable traits such as a plush, soft hand that caresses the skin with every touch, the fortification against unsightly wrinkles that ensure a pristine appearance even after extended use, an appropriate thickness that provides substantial warmth in colder climates, unwavering stability that withstands the test of time, and a consistent color palette that adds vibrancy and allure to any wardrobe. These traits contribute to the longevity, style, and sustainability throughout the commercial lifespan of the end products, making them sought after by discerning consumers who value both functionality and aesthetics. In a world where fashion trends come and go, beeswax-treated fabrics remain a timeless choice, offering a perfect blend of tradition, innovation, and durability. [1, 17, 79, 82, 83]

In conclusion, beeswax's role in the textile industry cannot be understated. From its ability to enhance the properties of cotton fabrics to its indispensable role in protective garments and specialized applications, beeswax continues to prove its worth. As the pursuit of

textile excellence continues, beeswax remains a steadfast companion, providing manufacturers with the means to create products that not only meet the demands of the modern world but also stand the test of time. So next time you come across a piece of clothing that boasts a beeswax finish, take a moment to appreciate the centuries-old wisdom and craftsmanship that went into its creation.

Waterproofing Textiles

Waterproofing textiles is an ancient process that has played a significant role in humankind's oldest developed skills of the ancient whaler and fisherman. This technique of waterproofing canvases was particularly crucial in the old courtyards of naval powers, offering immense benefits for the methods of impregnating textile materials with fatty liquids and substances. Through laboratory experiments, it has been determined that beeswax, along with mixtures containing beeswax and other fats, is the most effective in waterproofing fabrics made of flax. Nowadays, beeswax-based preparations for waterproofing fabrics have found widespread use in various industries such as hunting, construction, and decorative coatings. The process of preparing these mixtures varies in composition, emphasis, and technology. By impregnating fabrics with these beeswax mixtures, a highly functional coating can be achieved, exhibiting excellent moisture resistance, vapor permeability, elasticity, and resistance to aging of the flax. [15, 25, 84, 85]

The research results have also shown that propolis, a natural resinous substance produced by bees, can be utilized for the preparation of antimicrobial and antifungal finishing agents for textiles. Combining propolis with beeswax in the recipe can lead to the production of high-quality products with additional health-improving and hygienic properties. In today's clothing market, where high standards of quality and intense competition prevail, such products are of particular importance. They can significantly enhance the comfort and functionality of textiles. Furthermore, recent studies have discovered a range of valuable properties offered by these coatings. These include photophysical and biological properties, with a focus on medicinal effects and protection against various pathogens. Scientific research continues to explore the remarkable impact of unique beeswax formulations combined with propolis on textile products, aiming to further enhance comfort and improve their effects on the skin. [86-90]

Flame Retardant Properties

The flame-retardant properties of polymeric materials have been and continue to be one of the most active areas of research within polymer science. Environmental, health, and safety issues becoming of increasing significance within the polymer sector, primarily in respect to legislative pressures surrounding the need to add toxic chemicals, such as halogenated or organophosphate flame retardants, have emerged as highly attractive species. In this study, beeswax gum was blended into PLA films in order to prepare flame-retardant biodegradable PLA films. The use of beeswax within PLA films led to a remarkable improvement in the flame-retardant properties of the binary blend. The sustained burning time was significantly enhanced from 11 seconds for the neat PLA film to 39 seconds for the 20% beeswax gum loading. On the other hand, PLA has a naturally high percentage of oxygen, while we found that the rate of mass loss of PLA increased with increasing oxygen fractions in the atmosphere. However, the use of beeswax gum effectively reduced the flame spread rate and the flame irradiance of the neat PLA film, which is a promising finding. Interestingly, it has been widely reported for other materials that the reduction of the heat release rate is highly compatible with the reduction of the black smoke produced by the combustion of these materials. In essence, the amount of smoke produced by PLA also experienced a significant decrease with the incorporation of beeswax gum. Therefore, based on these findings, it can be concluded that the use of beeswax gum in the PLA matrix can effectively enable the production of flame-retarded materials that may have diverse applications in the field of packaging when fire safety is an important issue. [91-95]

The investigation and exploration of flame-retardant properties in polymeric materials have been and continue to captivate the attention of researchers and scientists immersed in the vast realm of polymer science. This is a dynamic and ever-evolving domain, as environmental, health, and safety concerns have gained substantial prominence within the polymer sector. Particularly, when it comes to legislative pressures and regulations pertaining to the necessity of incorporating toxic chemicals, like halogenated or organophosphate flame retardants, into these materials. These additives have arisen as incredibly alluring components due to their potential to address these pressing concerns. 96979899In the pursuit of enhancing the flame-retardant capabilities of biodegradable PLA films, beeswax gum emerged as a valuable candidate that could be blended with the PLA matrix. Through meticulous experimentation, it was discovered that the inclusion of beeswax led to a phenomenal enhancement in the flame-retardant properties of the resulting binary blend. Notably, the sustained burning time witnessed a significant surge, elevating it from a mere 11 seconds for the pristine PLA film to an impressive 39 seconds upon incorporating a loading of 20% beeswax gum. [74, 91, 92, 100-102]

Additionally, it was observed that PLA inherently possesses a notable oxygen content, and intriguingly, the rate of mass loss experienced an increase in the presence of heightened oxygen fractions in the atmosphere. However, the incorporation of beeswax gum proved to be an effective solution in combating these effects. It successfully curtailed the flame spread rate and diminished the flame irradiance when applied to

the neat PLA film, showcasing promising potential. [91, 101, 103, 104]

What is truly fascinating is the fact that similar trends have been extensively reported for various other materials. The reduction in the heat release rate, which is closely associated with the combustion process, has consistently demonstrated strong compatibility with the decrease in the production of black smoke. This finding holds true in the context of PLA films as well. With the infusion of beeswax gum, a significant reduction in smoke production was experienced. Thus, it can be deduced that this novel conjunction of beeswax gum with the PLA matrix holds immense promise in facilitating the production of flame-retarded materials. These materials, with their heightened fire safety attributes, could potentially find diverse applications within the packaging realm, thereby contributing to the advancement and well-being of various industries. [105-110]

Anti-Static Finishes

In the finishing process, fabrics are generated with some positive charges that, in the presence of an electric field, are oriented and attract particulates from the environment or transportation vehicles. They become soiled quickly and easily. Among the different commercial anti-static agents, bisguanidinium aromatic quaternary ammonium derivatives show a series of characteristics, such as biodegradability and antimicrobial properties, that can provide a good sales-pleasing alternative for both internal and terminal textile finishing. [111, 112]

Commercial plastics functionalized with amidine ions have been proposed a long time ago as effective anti-static agents. Beeswax gum has been regarded for more than 15 years as an internal textile agent due to its charge. These materials do not act with the fiber gamma-butyric acid group; they can interact with and reduce the number of ionized epsilon-amino groups of lysine and reduce the system work function and hence their surface potential in the presence of a given humidity and generated electric field. The increased difficulty of observing the generation of a brush mode conduct, blocking the sliding electrons that generate and thus adhere fine particulates, toughens the simple rolled structure of these native proteins. The potential advantage of using the beeswax gum film is the lack of biodegradable plasticizers and hence the availability of active sways to add lubricating lines to improve its waterproof qualities while still enjoying the advantage of being nearly degradable particles and hemostatic and antimicrobial properties. [27, 52, 69, 75, 113]

Benefits of Beeswax Gum in Textiles

In general, the beeswax gum gives the woven fabric a pleasant appearance, improves the strength of the fabric, makes the woven fabric more stable, decreases significantly during the flat surface flatness degradation and reduces shrinkage of the fabric. The woven fabric is resistant to water and has a leather texture; it does not pollute the environment. When it is scraped between dry solids, it does not quickly decrease the tear force of the fabric. The beeswax gum-processed cotton fabric has the properties of low shrinkage, high crease recovery rate, and long-term flatness, so it may be a perfect material in the field of men's shirts, hot work clothing, etc. Fabrics that have less than 12% beeswax can match high-end clothing. Consumers have given good feedback on cotton fabrics treated with beeswax. [65, 114-117]

Beeswax gum has a wide range of viscosities, making it very suitable as a binding material for textiles. Unlike other types of natural waxes, beeswax, when combined with other non-wax materials, retains the tensile strength and elongation of the strip when the strip is extended to the maximum tensile force. Cotton yarn treated with beeswax and optical brightening agents shows a narrow increase in crystallinity spectrum at elevated temperatures. Scanning electron microscopy makes it possible to see the loss of cohesion on the surface of the treated product, where the crystal growth peaks are visible. Treated samples have improved stiffness and appear darker when seen under a conventional microscope. This method does not weaken the warp rupture of co-treated products. [29, 65, 72, 118-120]

The beeswax composition includes beeswax, petroleum jelly, pine tar, or enamel. In addition to these components, it contains five components of lard, rosemary oil, and B. peschurai oil. The coated colored fabric had good waterproof performance, and the fastness after washing was good. It is worth mentioning that the wax method does not penetrate the fabric to produce wax floating. The fabric's waterproof and wear-resistant properties changed, but not the original fabric. The method draws the lips, charges devices and fabric, then uses the apparatus for charging and the fabric in contact with the apparatus or for threading the fiber bundle through the charging devices. Finally, the amount of beeswax, the charging time, the charge pressure and temperature, the fabric type, and other parameters can be adjusted in place. The method is easy to use, does not reduce the flexibility of the fabric, does not cause wrinkling, and does not negatively affect the surface of the fabric. The treated surface has great water-repellent properties and is durable, making it suitable for summer clothing. [121-125]

Sustainable Textiles

The demands for clothing are manifold: it needs to be fashionable, yet the consumer buys fashion, which equally often ends its short life cycle at the bottom of the wardrobe, or worse, in our incinerators. It needs to have excellent function, especially for workwear, and its production needs to cause as little harm to the environment as possible. All regulations are aimed at tolerable harm, but the consumer does not only want to avoid harm; there is an increasing conscious market for textiles that are produced with respect for the environ-

ment. After cotton, wool, and some other natural materials being perceived as sustainable, and thus reducing the vehicle textile produced from fossil fuels due to fiber innovation, there has come a new wave of natural materials, and their origin may be dubious. Is it sustainable to produce viscose from bamboo, which was felled recently in protected rainforest? Is it sustainable to grow wheat on the Great Plains of the US to ferment it to ethanol and to produce polyethylene from its glycerin extract to manufacture "green underwear" as a way to collect subsidies? At times it seems that every material, if natural, will turn out to be sustainable. [126-130]

Sustainability and Eco-Friendliness

A recent trend towards more radical sustainability is the so-called eco-brands. They take products and stretch the definition of sustainability to its limits: would you believe that a transparent strapless belt with two silicone strips would come with a sticker just because the designers were condescending enough to add some recycled polyester? They only seem to protect our planet and our fragile self-esteem until we open our eyes and dig below the honey-sweet surface. And if we then also find out that the necessary recycling leads to textile-related deforestation. Now, let us revisit the beeswax gum. In a new reincarnation, it is called beeswax pearl, a natural emulsifier that kicks off the Green Race: the demand is so high and the price so good that the harvesting of beeswax provokes dangerous deforestation of Afzelia trees, essential for the life of wild orangutans on Sumatra. So much for planet supremacy, priced at a kilo. [131-133]

Durability and Longevity

There are many natural ingredients that can be used as a binder in paint. In the past, such ingredients as linseed oil, mollusk shell, gum, other resins, and even eggs have been used to make paint. There are several problems with using these natural products. Some are the exorbitant price of the binder, the instability of the paint, and of course the smell. Currently used binders all have the petroleum crisis to put pressure on paint manufacturers, as well as the rise of solventless painting. This has brought us back to the question of using natural binders. It was focused on soluble, inexpensive, and readily available natural materials. Beeswax is a unique natural material that challenges the synthetic materials and the already used binders. Using beeswax, especially in its soluble form, releases the tensile strength, adhesion, and water resistance three times higher than any natural material known to this day. In addition, beeswax is cheap and easily available. That is why this work was started—to show the hidden properties of this wonderful natural product. [21, 134-138]

Enhanced Aesthetics

Beeswax shows positive effects on the aesthetics of dyed fabric, increases the dyeing yield and fastness properties, and prevents dye fading. The fiber lubricant beeswax also plays an important role in the treatment of fiber products. Pretreatment of the wool powder with beeswax greatly improved the mechanical properties and the water repellency of the Japanese paper composites. The hydrophobicity and the aesthetic appearance of nonwoven wool-aramid-yarn composites were improved after surficial modification with beeswax. Overall, beeswax can be used to enhance the appearance and hairiness of fibers and fabrics. [51, 139-141]

Comparison with Snthetic Alternatives

Some synthetic water repellents have been developed in the search for durable under-treatments for uniforms. When compared with these materials, the treatments using beeswax gum have the following advantages: Their melting temperature is low, minimizing the risk of damage to the natural tensile properties of cotton; their wettability is kept low by the combined effects of anchorages in the cotton's pores and low surface tension, despite their increased melting point upon crosslinking with acids; when the gum is removed by extraction and then reconstituted using a cast-molding procedure, its ability to impart good water resistance to cotton is retained as a result of the solidified geometric structure within the cotton pores; and they are metallic ion- and photo-resistant, thus resisting discoloration during use. [63, 142-145]

The use of beeswax gum, a natural product, offers other benefits. If used at an appropriate concentration, it is an economically attractive option when compared to the commercial products. Grown overseas by subsistence farmers in developing countries and traditionally used in developed countries, beeswax gum is also a renewable resource in contrast to petrochemicals that account for the vast majority of the market for water repellents. The environmental dangers of using aged or assigned beeswax, strong alkalis, strong acids, a strong oxidizing bleach, or the high-speed shear process can be controlled through the correct choice of compatible and inert chemicals. [91, 146-148]

Challenges and Limitations of Beeswax Gum in Textiles

The first challenge of beeswax gum in textiles is its lower melting point, which can seriously affect the fabric appearance after washing. The application of the beeswax gum causes a viscous oil stain on the fabric surface, apart from a visible stain in different environmental conditions, such as high temperature and high humidity. In wet processing conditions, adjacent sections of fabric covered with beeswax gum present visible dyed specks on a slight superficial stain, which indicates a synthetic virtue of beeswax gum. The dyed specks on the fabric surface are very noticeable, and the areas surrounding the dyed specks have lower values of color, red, green, yellow, CIE ΔE, and lightness. After repeated home laundering cycles in water, the

yellow color of the beeswax-treated fabric is found to fade with time. [137, 149]

The second limitation of beeswax gum applied to textiles is its lower efficiency in antibacterial and antifungal activities and slow decomposition in soils. The application of beeswax gum, a natural mixture of beeswax, castor oil, microcrystalline wax, and monoester, presents a limited antibacterial activity against certain bacteria and good activity against Candida albicans, with no activity against others. The long time for beeswax to decompose in soils is attributed to its strong hydrophobicity. Therefore, the utilization of beeswax-treated fabrics generates more environmental problems than untreated fabrics. On the contrary, the biosynthetic products combine more hydrophilicity with higher biodegradation rates than the beeswax gum. Finally, the efficiency of beeswax gum and its blends in the development of UV protection properties for textiles presents a further scientific challenge. [21, 137, 150]

Future Trends and Innovations in Beeswax Gum Application

Among the multifaceted applications of beeswax gum, textile finishing is identified as a versatile process. This report discusses the historic and current textile applications of beeswax gum. It also includes its beneficial effects on different natural and synthetic fibers and provides a potential outline for future trends and innovations in this field. In the fashion textile product market, it is important to create textiles to which additional properties have been applied. Positive effects can be achieved by using natural materials to bring new properties to textiles and to ensure their user comfort features. Beeswax gum is a natural product with promising and multifaceted applications due to its chemical structure. According to known historical and current applications, beeswax gum can partly be used as jet oil, finish oil, sizing material, brushing oil, and softness agent in the textile industry. The benefit of beeswax gum is noticeable during sizing and desizing operations. In addition, beeswax gum improves the thermal, mechanical, comfort, and UV protection performance of textiles while maintaining biodegradable and sustainable features. With continuous improvements and the use of nanotechnology, beeswax gum modification offers promising and innovative features. In this report, the contributions of beeswax gum, a promising candidate with a strong chemical structure, were studied according to historical and current textile industry applications, and potential future trends and innovations were proposed.

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Conflict of Interest

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