An Alternative Fiber Source in Sustainable Textile and Fashion Design: Cellulosic Akund Fibers

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Abstract Akund fibers are natural cellulosic fibers classified as seed fibers such as cotton, kapok, and milkweed. Akund fibers, which have structural and physical properties very similar to fibers such as kapok and milkweed, are a commercially widespread type. It stands out among natural fibers with its hollow fiber structure and low fiber density. It is accepted as a sustainable raw material source with features such as renewability, biodegradability, eco-friendly, nontoxicity, and similar features. The hollow structure of akund fibers, whose spinnability is weak as experienced in kapok and milkweed fibers, makes these fibers an important fiber source for advanced materials such as home textiles, composite textiles, and technical textiles. At the same time, studies on the development of the spinning properties of these fibers can be considered as an evidence of the potentiality of these fibers to be used as raw materials for the garment industry shortly. In this chapter, it is aimed to benefit future studies by summarizing the structure, properties, and utilization areas of akund fibers.

Keywords Akund fiber · Akund floss · *Calotropis gigantea* · *Calotropis procera* · Natural fiber · Sustainable textile · Hollow fiber

1 Introduction

Textile and fashion design often evoke the characteristics of visual concerns, such as the shape, color, or pattern of a product. Although visuality plays an important role in designing a product, designing a product also includes environmental and social responsibilities. Especially with the introduction of the sustainability concept into our lives, this concept has become a parameter as important as visuality in

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many areas. Sustainability is based on the necessity of today's generation to meet the requirements of future generations without compromising the requirements in a system that includes the efficient use of natural resources, environmental order protection, and economic growth [1–5].

The textile industry, which is one of the largest industrial areas in our planet, has a huge responsibility for creating a sustainable future. Many small and large companies seek to develop different solutions to raise awareness about sustainability and contribute to sustainable production. Bringing sustainable technology and methods to the textile industry, reducing the environmental burden of existing technologies and methods, using clean energy sources, etc. are among the studies carried out to make the textile industry more ecological [6–14].

Although most of the textile industry's raw material needs are met with petroleum-based synthetic fibers, the number of efforts to enhance the utilization of natural fibers or biodegradable synthetic fibers is increasing day by day [15–24]. The use of recyclable, reusable raw material sources that do not harm nature can be considered as one of the most basic methods that can be applied in sustainable textile and fashion design [1, 4, 5].

With increasing awareness in the society about environment-friendly production and sustainability concepts, it is observed that demand from the society is shifting toward products that use more natural materials, are exposed to fewer chemicals, and even harm the environment during production. Just for this reason, it is observed that the demand for products produced from organic cotton, in which chemical pesticides are not used, instead of cotton fibers, which are the most broadly used natural fiber type in textile, has increased significantly [2, 25].

As an outcome of the fast-changing fashion, growing world population, consumption habits, and limited efficiency in recycling, etc. methods, fiber demand in the world is increasing every year [26–28]. It seems possible that the demand, which is 100 million tons today, will reach 140 million tons in 2030 if the current rapid increase continues [29].

According to the recorded data, 100 million tons of fiber were used in 2018. Fifty-five million tons of this consumption is polyester, 26 million tons of cotton, six million tons of cellulosic, five million tons of nylon, two million tons of acrylic, and one million tons of wool [29].

Synthetic fibers constitute the fiber group with the highest usage rate in the textile industry. Recycling or recycling these fibers is very important in terms of reducing the environmental burden in textile production [26–28]. Otherwise, it creates an ever-increasing environmental burden and harms nature globally. Unfortunately, according to 2018 global fiber consumption figures, the share of recycled polyester among 55 tons of polyester consumption remains at 20,000–30,000 tons [29]. Tons of textile waste mountains have already been formed, and this situation will inevitably bring sad results if permanent solutions are not developed.

In addition, when we look at the total fiber consumption figures in the world, it is observed that the amount of natural fiber production is at very low levels next to the raw material need of the textile industry. Dissemination of natural fiber types that could be an alternative to synthetic fibers according to their usage areas is of great importance in environmentally friendly textile production.

The amount of natural fiber production carried out today is very low in addition to the raw material need of the textile industry. For this reason, natural fiber types that could be an alternative to existing raw material sources and the dissemination of production of these fibers are investigated.

Textile fibers obtained from agricultural wastes such as pineapple, banana, coconut, and raffia fibers can be evaluated as alternative textile fiber sources [30–32]. However, the majority of fiber sources obtained from agricultural wastes are included in the lignocellulosic fiber class. These fiber types, whose cellulose ratios are generally not very high, can be widely preferred especially as composite reinforcement fibers [33–35].

Akund fibers are a type of natural cellulosic fiber [36–40]. Akund fiber, which belongs to the class of seed fibers such as cotton and kapok fibers, exhibits very similar characteristics to kapok fibers in terms of both fiber structure and fiber characteristics [36, 40–46]. For this reason, it is possible to mix it with kapok fibers from time to time [41]. Akund fibers do not need any fertilizers and pesticides that may harm the environment during fiber production, unlike cotton fibers, and can be grown even in arid environments [47]. Therefore, they are nontoxic and abundant [35]. Akund fibers, which have a shiny appearance like silk and touch like cotton, are accepted as an alternative natural fiber type. In this study, detailed research on the structure, properties, and end-use areas of akund fibers is included.

To minimize energy and water consumption in the process steps of textile and fashion design, both textile industry employees and scientists devote significant time and budget to research. Since seed fibers such as akund, kapok, and milkweed are obtained from plants that grow naturally in nature and can be easily grown without the need for any pesticides, fertilizers, or even irrigation, they have become a promising textile material in regions with suitable climates for agriculture, especially in Asian countries. In some studies, akund fibers are described as a new ecological and cellulosic textile material with a great development potential [48]. In this chapter, it is aimed to benefit future studies by summarizing the structure, properties, and utilization areas of akund fibers. The next part of this book chapter will give information about the akund plant.

2 Akund Plant

Akund fibers are found in *Calotropis procera*, a member of the Asclepiadaceae botanical family [38, 41, 42, 49–52], and *Calotropis gigantea* [37, 38, 42, 47, 49, 51–56] plants. Akund fibers are fixed to the seed at one end and to the inside of a capsule-shaped fruit that surrounds the fibers at the other end [37, 52, 53, 57]. When the fruit is fully ripe, the capsule opens, and the aquatic fibers surrounding the seeds in the capsule are easily dispersed by the effect of the wind, as in dandelion flowers [36–38]. The average length of the capsule before opening is 6 cm and its weight is around 0.04–0.10 g [52, 53]. A single seed in the capsule weighs approximately 4 mg and is 6 mm long [53].

Akund fibers can be easily grown in poor soil without the need for fertilizers and pesticides, especially in countries such as China (Guangdong, Guangxi, Hainan, Sichuan, Yunnan regions), India, Indonesia, Lagos, Malaysia, Nepal, Burma, Pakistan, Bangladesh, Senegal, Mauritania, Sri Lanka, Thailand, Brazil, Vietnam, Iran, and other countries with subtropical climates [37, 38, 40, 41, 47, 49, 53, 54, 56, 58, 59]. Its natural plantation is in regions up to 1300 m above sea level, in semiarid conditions with annual precipitation between 150 and 1000 mm [58]. Akund plant grows in sandy and heavily drained soils and is resistant to climatic changes and various soil textures [55, 58, 59].

It is stated that the akund fibers grown in India begin to bloom in January–March, and the harvest is carried out in April–May [54, 56]. Harvesting is mostly done manually several times depending on the maturation of the fibers [54]. Akund fibers are obtained as a result of drying and opening the capsules, provided that they are constantly turned upside down in the sun for about 3 days. Akund fibers obtained are known as cotton-like fibers with their white and shiny appearance [55, 56]. The quality of akund fibers is determined depending on the color, smell, moisture of the fibers obtained, and foreign materials such as seeds, dust, and soil mixed between the fibers [54, 55].

Akund plant (*Calotropis procera*) is a multipurpose plant species that are frequently used by traditional healers and the public in medicines prepared for the treatment of many diseases and disorders [55, 58, 60]. Both *Calotropis procera* and *Calotropis gigantea* species belonging to the Asclepiadaceae family have enormous disease prevention potential against various infectious agents such as bacteria, viruses, fungi, protozoa, and worms, as well as being widely used in the treatment of different diseases and psychological disorders [58]. In the next section, information about akund fibers and their structure are given.

3 Akund Fibers and Their Structure

Akund fibers, also known by different names such as "akund silk," "akund floss," or "calotropis" [42, 49, 55, 56], are a single cell fiber [36, 42, 53, 54, 57]. These fibers, which have a thin wall, have a large space in the form of a long tube filled with air [38, 39, 61]. Akund fibers can be identified with large internal cavities and surface hydrophobicity [62]. This gap in the fiber structure constitutes 80% of the fiber [36, 38, 57]. The fibers are untwisted and in the form of straight strips [54]. The fiber cross section of akund fibers varies between 12 and 42 microns whose fiber length varies between 2 and 4.5 cm [42, 54, 57, 61, 63]. The linear density of the fibers is around 1 dtex [57]. The wall thickness of the fibers is 1.4–4.2 microns [54]. Akund fibers have good biocompatibility [39].

In proportion to the similarity between the kapok plant and akund plant, there are also great structural similarities between akund fibers and kapok fibers [56, 64]. Both fiber types are hollow, thin cell-walled, soft, shiny, warm feeling, light, and weak-strength fibers [65–67]. Their images under the microscope are also quite

Table 1 Comparison of akund fibers with similar seed fibers [35, 53, 61, 63, 64, 68–70]

	Akund	Kapok	Milkweed
Cellulose	55.45	35–65	52–55
Hemicellulose	21.91	22–45	24
Lignin	16.15	13–22	18–21
Pectin	0.32	0–23	0–4
Wax	4	2–3	1–2

Table 2 Comparison of akund fibers with similar seed fibers [38, 57, 69–71]

	Akund fiber	Kapok fiber	Milkweed fiber
The breaking strength (cN/dtex)	3.42	1.4–1.7	3.3
Elongation at break (%)	2.6	1.8–4	3
Moisture regain (%)	13.5–13.8	0–11	9.6–11.1
Density (g/cm^3)	0.9–1.1	0.4	0.97

similar to each other. However, the netlike thickening mainly observed in kapok fibers is not visible in akund fibers [42, 56, 65, 66].

The amount of crystalline region contained in akund fibers, which contain more lignin compared to kapok fibers, is around 28.92%. Akund fibers, which have a nice touch like cotton, also have a nice shine like silk fibers [38, 61, 63]. The majority of studies show that akund fibers exhibit better mechanical properties than kapok fibers [57].

In Table 1, the structural characteristics of akund fibers and cotton fibers and kapok fibers are compared. Akund fibers can be accepted as one of the lightest known natural fibers with a density of 0.90–1.14 g/cm^3 [29, 53, 57] (Table 2).

4 Properties of Akund Fibers

4.1 Mechanical Properties

The breaking strength and elongation at break of akund fibers are higher than kapok fibers, but these values are lower when compared to cotton fibers [57, 71]. The breaking strength of the akund fibers (dry form) was reported as approximately 3.42 cN/dtex [57, 71] (Table 2). With the enhancement in the amount of relative humidity in the air, an increase is observed in the breaking strength of the akund fibers [57]. This can be attributed to probable alterations in the interaction between large molecular chains as an outcome of water molecules penetrating the fiber structure. The water absorbed by the akund fibers causes the unevenness of the macromolecules to increase. It has been observed that the elongation percentage at break of dry form akund fibers was recorded as 2.6 on average [71]. The compressive-resilient property of akund fiber as wadding fiber exhibits satisfactory values [71].

4.2 Moisture Regain

The moisture regain of akund fibers is around 13.5–13.8% [38, 57, 71], which is higher than that of cotton fibers [38]. While akund fibers exhibit a quick moisture release feature, the moisture absorption performance of these fibers is slow [38]. The initial rate of moisture release of akund fibers is higher than that of cotton fibers, akin to that of kapok fibers. However, the initial rate of moisture absorption is quite low [71].

In addition to exhibiting structural similarities with kapok fibers, there are also similarities in their moisture absorption properties. Their ability to absorb and release moisture is similar to that of akund fibers and kapok fibers. Under standard conditions, the moisture content of akund fibers is slightly higher than that of kapok fibers [61].

4.3 Antibacterial Activity of Akund Fibers

It was determined that Li et al. 2019 [71] evaluated the antibacterial activity of akund fibers; however, akund fibers did not exhibit any antibacterial properties against *Staphylococcus Aureus* [71].

4.4 Spinnability of Akund Fibers

Owing to the low cellulose content of akund fibers, the spinnability (ability to be spun into yarn) is low [40, 42, 72]. In addition, the hollow structure of the fibers and the fact that this hollow structure is 80% make the fibers lighter and brittle, which negatively affects the spinnability of the fibers [72]. However, during the formation of yarn, there must be sufficient frictional force between the fibers forming the yarn so that the strength of the formed structure should be sufficient to maintain the yarn structure. However, it is very difficult to provide sufficient friction force within the yarn structure due to the smooth fiber surface of akund fibers [47, 72]. For this reason, it is preferred that these fibers are spun as a mixture rather than spun alone. It is also possible to increase the friction force between the fibers by treating them with $CaCl_2$ or glycerol before the spinning process [47].

Moreover, it has been noted that sizing agents such as polyvinyl alcohol (PVA) and acrylate and their mixtures at different rates can be used to enhance the spinnability of akund/cotton blended yarns and to prevent loss of strength, breakage, and similar physical damages that may occur during spinning [73].

Separation of akund fibers from the capsule can be performed using the airflow method [72]. It is probable to obtain high-quality fibers from these fibers by using new carding wires. To reduce the number of short fibers and neps, the combing length (width) during combing should be longer than the length of the akund fibers. Cotton/akund fiber blended yarns can be successfully spun at 18.45 tex fineness at 40/60 or 33/67 blend ratios [74, 75]. Cotton/akund blended compact yarn shows less hairiness and more advanced mechanical characteristics. However, there are some difficulties while weaving these blended yarns, and there is no model developed to solve these difficulties [47, 74, 75, 76]. The difficulties experienced during the weaving process are generally due to the low strength, high hairiness, and poor abrasion resistance of the yarns. To alleviate the effects of these weak features on the weaving process, it is necessary to develop an appropriate sizing process [47].

4.5 Pretreatment Processes of Akund Fibers

Akund fibers are fibers with high potential for use both in textile products and as fiber reinforcement in composite structures. During their use in these application areas, various pretreatments or treatments with chemicals may occur. Changes in fiber structure, fiber content, and fiber performance properties as an outcome of pretreatment processes of akund fibers are of great importance. For example, in a study examining the change in fiber characteristics as a result of pretreatment of akund fibers with sodium carbonate, as a result of the process, it was noted that the amount of noncellulosic material in the fiber structure decreased, but no significant change was observed in the chemical content. In addition, it was reported that the roughness on the fiber surface increased, and the fiber strength and fiber weight were lost, while the elongation values at the break of the fiber enhanced slightly [37].

In a study investigating the usability of akund fibers in the composite structure, akund fibers were pretreated with 15% NaOH solution for 1 h. It has been reported that mechanical characteristics such as flexural strength and tensile strength of the composite structure were improved after alkali treatment and akund fibers can be an economical and environmentally friendly alternative to synthetic fiber composite structures [35]. In the next section, information about the utilizations of akund fibers are given.

5 Uses of Akund Fibers

The usage areas of akund fibers are mostly common with kapok and milkweed fibers, where they exhibit similar properties. However, its commercial use in textile products is not very common. As a result of research on sustainable testis products and production methods, akund fibers can be accepted as an ecological, renewable, biodegradable raw material source [77]. Many products match the fiber structure and performance characteristics of akund fibers and can be designed by benefiting from the characteristics of these fibers. The current and potential uses of akund fibers are summarized in Table 3.

Table 3 Current and potential uses of akund fibers

Uses	References
As for filling material	[42, 50, 60, 78]
As insulation material	[42, 79]
As fiber reinforcement in composite materials	[33–35, 39, 51, 80–83]
Biological templates for advanced materials	[62, 79]
Home textiles and clothing in blended yarns	[54, 57, 75]
Fishing nets and ropes	[63, 78]
Oil sorbent materials	[62, 84–87]
Supercapacitors	[88]

Various information is available in the literature for the ability of akund fibers to float in water and their water resistance [42, 57, 70]. It was stated that although akund fibers exhibit similar properties with kapok fibers, it is not possible to use these fibers as fillers in materials such as life vests, since the ability to float on and resist water is low [42]. However, in different sources, it is stated that akund fibers can be used as fillers in glass rescue vests and life buoyans, and even in India, these fibers are used in fishing nets and fishing line threads [54, 89]. It has been noted that in Rajasthan and its environs in India, akund fibers are utilized in the manufacturing of ropes and similar materials and that it is stronger than hemp (sun hemp) and can replace it (more on that in the source) [49].

Akund fibers can be used in the production of thick yarns in a mixture of cotton fibers [54, 74, 75]. Studies conducted in recent years have proven that yarns that can meet the basic properties of akund/cotton fiber blend yarns that can be used in home textiles and clothing can be developed. In addition, studies to improve the usability of these fibers continue [57].

There are also studies aimed at improving the spinnability of akund fibers [90]. In these studies, it was aimed to improve the spinnability of the fibers and to expand their usage as yarn or fabric both in the textile industry and in other industries [90].

The usage of natural fibers in fiber-reinforced composite materials has become widespread in recent years, and various natural fiber types are being researched especially to produce composite structures with improved economic and performance properties [33, 83]. For the composite structure to be strong and durable, the moisture-absorbing properties of the fibers to be used in the structure should generally be good. Akund fibers have a very high ability to absorb moisture [81, 82]. In this context, the utilization of akund fibers as fiber reinforcement in composite structures is among the current research [33, 34, 82, 83].

In addition, the hollow structure, biocompatible character, and very lightness of akund fibers make these fibers a very important fibrous material option for many industrial areas, especially the defense industry. They are suitable for use as a template that can carry various nanomaterials to perform special functions [62]. For example, the development of conductive biocomposites has been made possible with the help of various metal particles [zirconia (ZrO_2)] or conductive chemicals such as polypyrrole [39, 79]. As a result of impregnation with zirconia (ZrO_2) by using akund fibers as a template, fibers that provide thermal barrier can be obtained with the highest thermal stability and the lowest thermal conductivity properties of zirconia [79]. In another study, carbon dot (CD) loading was applied in the inner cavity and fiber surface of the akund fibers to gain fluorescence properties. At the same time, it is aimed to gain antibacterial properties by synthesizing silver nanoparticles in the fiber [62].

Many studies describe akund fibers as materials with superior oil absorbing performance [62, 84–87]. It has been noted that various chemicals can be loaded on the fiber surfaces of akund fibers as catalysts and water treatment agents. However, in these studies, since the chemical loading is only on the fiber surface, it shows easy shedding and weak stability. Therefore, the resistance to washing (washability) is very limited [62].

6 Sustainability Potential of Akund Fibers

Since akund fibers are not a commercially common fiber type, detailed life cycle analysis, carbon footprints, water footprints, CO_2 emissions, and similar studies have not yet been conducted for sustainable analysis of these fibers, both in industry and academia. Akund fibers are believed to have very similar structures in both their chemical and physical properties and are very similar to kapok and milkweed fibers in their effect on the environment [36, 40–46]. The natural, nontoxic cellulose structure of these fibers, their renewable and biodegradable nature [77], and the fact that no fertilizers or pesticides are required for their cultivation [2, 25] and that they can be easily grown even in dry soils [91] support the potential of sustainable natural resources. It is believed that it can be an alternative to kapok and milkweed fibers, which are often preferred as sustainable natural fiber sources and have gained popularity among natural fiber sources in recent years.

7 Conclusion

With the introduction of the concept of sustainability into our lives, there are great changes like reform both in our daily consumption habits and in the decisions taken on an industrial scale. Considering the depleted and polluted resources, these changes, which have become mandatory, reveal the necessity of considering every step to be taken industrially, every decision to be made, and the results to be calculated in detail. In industrial production, especially in sectors with a high environmental burden such as textiles, from raw material selection to methods and technologies, energy consumption, and water consumption values, features such as post-use recyclability or biodegradability are of great importance.

In the textile industry, which is dominated by synthetic fibers, recycling rates are unfortunately very low when compared to fiber consumption rates, and this causes increasing garbage mountains and serious pollution every year. For this reason, the utilization of natural fibers and the use of biodegradable, renewable, environmentally friendly fiber types are preferred, especially in production areas where sustainability is at the forefront. New generation natural fiber sources have an important potential at this point. Akund fibers have become an important fiber type for both daily textile products and advanced technical textiles, which have come to the fore in recent years. They are considered as ecological fibers with features such as renewability, biodegradability, nontoxicity, not needing any pesticides, etc. during production. With its hollow fiber structure and low density, it creates an important potential for advanced materials. Akund fibers, which we do not encounter very often in textile structures due to their low spinnability, are thought to be used in much wider areas soon, with research aiming to improve their spinning properties. Considering the recent development in the use of kapok and milkweed fibers, which are very similar both in structure and properties, it is anticipated that akund fibers will undergo a similar popularity process. The use of fibers as a template, especially in the design of materials with an advanced hollow structure, and their utilization as natural fiber reinforcement in composite materials have as much potential as the textile fashion industry and home textile products.

This study was aimed to shed light on future studies by summarizing the structure, properties, usage areas, and potentials of akund fibers obtained from the literature. Considering the research, akund fibers create an important raw material potential for technical textiles, the garment industry, and home textile. One of the most important reasons for the spread of these fibers is that the natural structure and eco-friendly properties of these fibers support sustainable textile production.

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