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An Eco-friendly Trend of Jute Fabric in Wet Processes of Textile Manufacturing

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Abstract

Jute which is known as the golden fibre of India is a natural bast fibre that has silky luster, high tensile strength, low extensibility, good aesthetic appearance. Jute is chemically known as ligno-cellulosic fibre, and it is bio-degradable and available in large quantity with low price and traditionally used as packaging material and carpet backing, ropes and cordage, but due to the eco-friendly nature of this fibre today jute is looked upon not only as a major textile fibre suitable for packaging but also used for making diversified and value-added products including upholstery, furnishing textiles and even wearable textile as it is used as a raw material for manufacturing dyed and printed textiles with a substantial improvement of colour yield, levelness of dyes, and fastness properties for jute fabric. The current review aims to highlight the concerns and challenges faced during the development of jute from such as packaging material to a textile fabric with enhanced sorption properties that can be dyed or printed with deferent types of natural and synthetic dyes by simple and cost-effective modifications using natural sources.

Keywords: Jute, Eco-friendly, Natural dyes, Dyeing, Printing.

Introduction

Jute, which is called the Golden Fibre of India, is a natural fibre under the category of bast fibres. It is an agricultural product which is chemically referred to it as ligno-cellulosic fibre. It possesses a silky sheen, excellent tensile strength, minimal extensibility, and a nice aesthetic look. It is reasonably priced and offered in an endless supply. Jute is environmentally benign and biodegradable. For decades, the classic jute products such as soil saver, webbings, carpet backing cloths, ropes and cordage, etc. have exclusively been used in the technical textile industry. Furthermore, new research has shown that jute may be used in place of a number of pricey fibres to create creative items like technological textiles. [1, 2] Jute is mostly produced in India, with Bangladesh coming in second. Assam, West Bengal, Andhra Pradesh, Orissa, and other states cultivate jute. The current global jute output is estimated to be 3.2 million MT, with 77 jute mills dispersed throughout India producing roughly 1.8 million MT of jute goods. Tropical, subtropical, and equatorial regions are where jute is mostly grown. Myanmar, Nepal, China, Vietnam, Thailand, and Brazil are some of the other main jute-growing nations. [1, 3]

While most jute fibres are still traditionally used in the industry to make jute cloths, there are many other variations as well, including hessian, sacking, carpet backing, soil saver, geo-textile, and ornamental. However, jute may be easily utilized for garments because to its post-finishing processes. Jute is not recommended for use in clothes, but because of its great strength, excellent abrasion resistance, and heat resistance, it may be used to construct protective garments that can withstand both heat and fire. The most common technical textiles in this industry made of jute are winter coats and upholstery that is fire resistant. Jute and acrylic can be used to provide a more pleasing visual and tactile experience. Nonwoven jute felt can also be utilized inside coats as an inner lining or filler.[1] Jute fibres can be blended with different natural fibres such as cotton, wool, linen and bamboo fibres. Jute fibres can also be blended with synthetic fibres such as acrylic and polypropylene.

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These blends is carried out aiming to: (i) enhance the fibres' performance during the processing phase; (ii) add functional properties to the yarn and fabric; (iii) enhance the fabric's aesthetic appeal; (iv) add a fancy effect; (v) lower the cost of the finished product; (vi) identify an appropriate natural origin admixture to help bridge the gap between the supply and demand for raw jute; and (vii) identify an appropriate route for lesser-known fibres for which a separate spinning system is not widely available or established.[4-8]

Extraction and Preparation Processes

The plants are usually cut by hand then tied into bundles according to height and diameter. The bundles are kept standing in the fields for 3-4 days to get dried, then carried to canals, ponds or any other water bodies for traditional retting for about 15-18 days. During retting, bacteria degrade the soft tissues that surround the fibres and bundles. When the bark readily separates from the core, the retting process is finished. and the fibre can be easily extracted by hand. To completely remove all of the dirt, gum, unnecessary plant materials, and retting residues, clean water is utilized for washing. Before being stored, the cleaned fibre is pushed out over a bamboo perch or bar to dry completely in the sun for 4-7 days. [9, 10]

Chemical composition of jute fibres

The jute plant has three main chemical component categories: cellulose (59–63%), hemicellulose (22–26%) and lignin (12–14%), along with a few additional smaller components including lipids, pectin, and wax. [11]

Comparison of jute with cotton as the largest natural Fibre

After cotton, jute is known as the second most significant natural fibre in the world. As a cellulosic fibre, jute is ranked second in terms of natural fibre manufacturing, after cotton. It was said that jute fibre produced fine white thread was more strong than cotton thread. As a composite fibre made of alpha-cellulose molecules and cementing agents like lignin and hemicelluloses, jute differs from staple fibres like cotton and genuine filament fibres like silk or viscose filament. That is why Jute will find a comfortable home in the textile industry alongside fibres like cotton and wool. [3, 9, 12]

The anisotropic crystalline/semi-crystalline cellulose microfibrils in jute, a ligno-cellulosic multi-constituent fiber, serve as the load-bearing entity, while the isotropic non-crystalline lignin portion serves as the matrix material and hemicellulose acts as the coupling agent. You can't pinpoint exactly where a chemical reaction is taking place on jute to a single component. Chemically treating jute may typically significantly reduce its fiber strength. In order to prolong jute's use as a textile fiber, it is necessary to minimize the degradation effects of the majority of chemical treatments. Due to the comparatively small amounts of lignin and hemicellulose in comparison to the abundant cellulose in cotton, the chemical processing of jute (lignocellulose) varies significantly from cotton (cellulose). Chemical processing and modification of jute must be developed, regulated, and standardised independently of cotton, as existing recipes are not suitable for jute

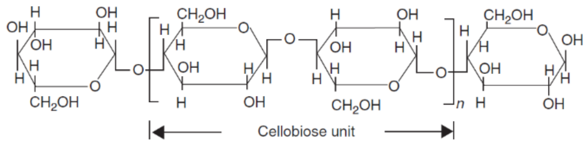

Figure 1: Chemical structure of alpha-cellulose

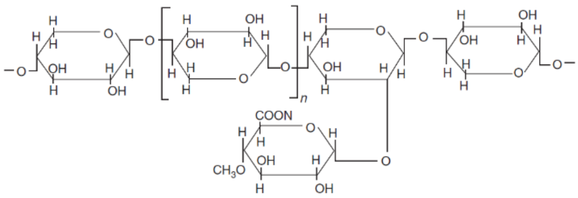

Figure 2: Chemical structure of hemi-cellulose

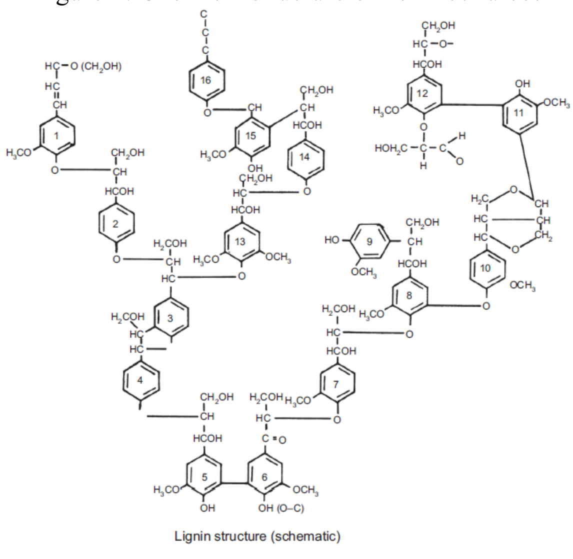

Figure 3: Chemical structure of lignin

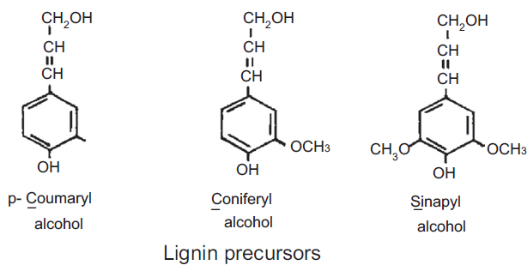

Figure 4: Lignin precursor

Table 1: Difference between Jute and cotton

Property	Jute	Cotton
Ultimate cell length (mm)	0.8 to 6.0	15 to 35
Length / Breadth Ratio	110	25,000
Fineness (Denier)	15 to 35	2.5 to 3.5
Tenacity (gm/denier)	3 to 5	3 to 4
Elongation at break (%)	1.0 to 2.0	8 to 10
Density (gm/cc)	1.45	1.56
Moisture Regain (%) at 65% R.H.	12.5	8.5
Composition (%)		
Alpha-Cellulose	59 to 63	89 to 96
Hemi-Cellulose	22 to 26	Traces
Lignin (insoluble resin like substance)	12 to 14	Traces
Oils, fats, waxes, etc.	03 to 04	2 to 3

Preparation Processes on Jute

After the Fibres are dried it were transported to the jute processing industry as bales or bundles. The kind of product to be made and its intended application are the key factors in careful selection of the raw materials. Firstly jute fibres are graded chosen for the intended product. After that, the fibres go through the processes of carding, drawing, and spinning to become yarn. The yarn bobbins are transformed into thread cones for additional warping and beaming operations, which include sizing. Jute may be found in fabric, yarn, and fibre form. Fibre: Untreated or treated fibres used to create fibre-reinforced composites and elegant woven bags. Yarn: Can be spun by traditional flyer spinning, the recently developed ring spinning and DREF spinning, It can be single, plied, or cord made 100 present of jute or mixed with other fibre. Fabrics: It might be union textile or 100% jute or blending of yarns. While conventional jute looms still make up the bulk of looms, shuttle-less looms such as projectile and rapier looms are becoming more and more popular in the industry for producing jute fabric (including sacking, soil saver, geo-textile, hessian, carpet backing and many more variations). Modern nonwoven and knitting techniques, as well as classic and contemporary weaving techniques, May be used to create these textiles. Nowadays, post operations are applied on jute fibres depending on the required type of fabric as well as the end functional application.[1] The essential finishing treatments are often applied in the form of yarn or fabric, but they can also be applied in the form of fibre if necessary.

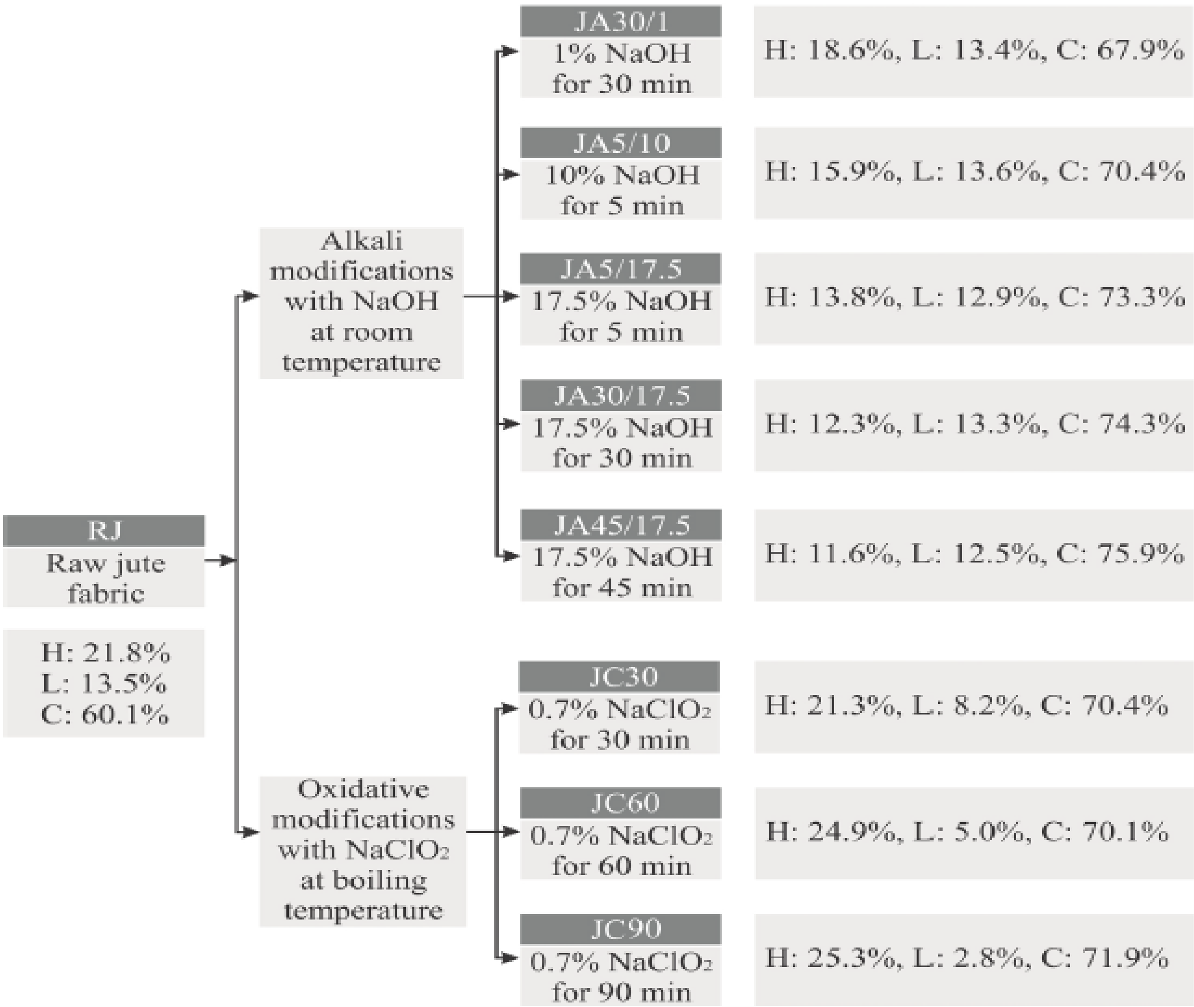

Figure 5: chemical composition of jute fabric before and after treatment

The finishing treatments include woollenization/ bulking (similar to mercerization), dyeing, and printing. In order to obtain jute fabrics with enhanced absorption properties, alkali modification is carried out on the raw jute with sodium hydroxide (NaOH) or oxidative modification is carried out on the raw jute with sodium chlorite ($NaClO_2$). The alkali modification involved the chemical modifications of raw jute fabric at room temperature using a 1:50 liquid ratio of NaOH solution.

The resulting modifications were then neutralized with a 10% CH_3COOH solution, rinsed with 0.5% $NaHCO_3$ solution, dried at room temperature, and washed again with distilled water. On the other hand, a $NaClO_2$ solution (pH 4-4.5) was used to perform oxidative modification on raw jute fabric at boiling temperature, followed by a distilled water wash, a 2% $NaHSO_3$ solution rinse, another distilled water wash, and then drying in room temperature. Alkali and oxidative chemicals are % grade, changing concentration of chemical agent and modification duration affects the obtained jute fabrics with different contents of (hemicellulose, lignin and cellulose content). [3]

Effect of Chemicals

Effect of Acids on Jute

Due to the phenolic hydroxyl groups found in lignin and the gluco-uranoic acid residue found in hemicellulose, jute has a mildly acidic character. In addition to being mildly acidic, jute is also chemically affected by acids. Because lignin is included in jute, it has a kind resistance to acid action than cotton. Inorganic acids hydrolyse cellulosic chains more rapidly than the organic acids, that is because inorganic acids are more effective on jute than the organic types.[2, 9]

Effect of Alkali on Jute (Sodium Hydroxide NaOH)

Jute gains a reddish red colour with very no weight loss when mild alkali, such as soda ash, borax, ammonia, etc., is added to a cool aqueous solution. However, when jute is cooked in an aqueous soda ash solution (w10% strength), weight loss happens (about 10%). Hemicellulose and other jute components are highly soluble in caustic soda. The degree of solubility often changes with temperature, time, and alkali concentration; the influence of concentration is most noticeable in this regard when it exceeds 10%. Jute gets crimps in it at 8%–18% NaOH. The early step of the reaction between jute and caustic soda proceeds quite quickly, virtually finishing in one hour. When using an 18% NaOH solution at 25 ^{0}C, around 50–60% of the hemicellulose dissolves, this process is known as the woollenization of jute. Jute fibre becomes flexible and soft due to a low alkali concentration. Even after slight treatment, a little amount of lignin and all of the acetyl group are dissolved. Jute treated with weak alkali retains its strength, while treated with strong alkali loses up to 25% of its fibre strength. [2, 9]

Effect of With Reducing and Oxidizing Agents on Jute

Jute is very sensitive to the effect of various oxidizing agents, the type of oxidizing reagent employed and the reaction conditions determine how much it is affected.[2, 9] Sodium chlorite and sodium hypochlorite are the most common bleaches used for jute. They work on dissolving the out lignin from jute making it whiter as the natural yellow to reddish colour of jute is due to the presence of lignin, and this process is known by bleaching of jute. The partial removal of lignin makes jute weaker as the middle lamella, which is almost lignin, between the ultimate cells gets weakened. On the other hand, jute fibres become finer.[9] Jute can be treated with specific oxidizing agents in an aqueous medium, such as H2O2, calcium and sodium hypochlorite in alkaline medium, KMnO4 and NaClO2 in acidic medium, and peracetic acid in neutral medium, to achieve different levels of whiteness, from pale cream to milk-white. However, it also has been documented that some reducing chemicals, such SO2 and Na2S2O4, are used to bleach jute in order to produce some less expensive goods. The most popular bleaching technique among the others seems to be H2O2 bleaching, because it can quickly achieve a very high degree of whiteness while losing a fairly little amount of strength and weight of jute fibre. Jute's dye ability with a basic dye was significantly improved after oxidation using any of these methods.[2]

Effect of Metal Salt and Complexes on Jute

Jute can be treated with salts of metal such as iron, manganese, chromium, zinc, copper, antimony and cobalt that can be done separately or in selected combinations to improve its weathering resistance and rot resistance. also the use of di-ammonium combination of DAP, phosphate (DAP) and ammonium sulphate/sulphamates and rochelle salt makes jute fire-retardant, however, the DAP approach is generally cost-effective, but the fabric's strength is significantly reduced.[2]

Effect of Enzyme Treatment on Jute

Enzymes, sometimes referred to as "bio-catalysts," are proteins that catalyze particular chemical reactions. The kind of enzyme and the process it is used in determine the enzyme's best activity. Enzymes can cause coagulation, reduction, oxidation, hydrolysis, and decomposition; however, the majority of common enzymes mainly cause hydrolysis. Certain textiles are suitable candidates for cellulase enzyme treatments because they include both cellulosic and lignocellulosic. In several applications involving cellulosic fibres, cellulases enzymes have been utilized to achieve surface polishing through decreased hairiness, bio-softening, enhanced water absorption, and also for the elimination of contaminants and sizing agents. There are numerous reports in the literature on how enzyme treatments can improve the appearance, feel, and other textile-related characteristics of jute fibre. Enzymes and bacteria break down the soft tissues surrounding the fibres and fibre bundles during the jute retting process, this process remains until the bark can be readily separated from the core.[2, 9]

Colouration of Jute Fabrics

Dyeing and printing are the two methods for any textile fabric Colouration. For dyeing or printing jute fabrics, preparation processes such as scouring, bleaching and mordanting must be carried out first to improve the fabric absorbency and improve the whiteness and brightness of the fabric by reduction its yellowness. These treatments result in achieving a very good colour yield, fastness properties and uniform colours in subsequent dyeing or printing processes.[13-15] Overall jute fabrics may be coloured with synthetic dyes such as direct, acid, basic, reactive, vat and sulphur dyes.[2, 16, 17] For example in case of basic and reactive dyes it was found that the exhaustion and k/s of basic dye are higher than reactive dye on jute fabrics, but the results of fastness properties of jute fabric with reactive dye is higher than fastness properties of jute fabric with basic dye, that is due to the formation of a very weak bond between basic dye and jute.[17] And in case of direct dye on jute fabrics, it was found that the results of fastness properties to washing was good to excellent, for light was good, for dry rubbing was good to excellent and for wet rubbing was poor to good.[16]

Jute also can be coloured with natural dyes such as dyes extracted from manjistha, annatto, ratanjot and babool.[2, 14, 15]

By talking about the green eco-friendly trend, all treating methods will be discussed using materials from natural sources.

Bio-scouring of Jute Fabrics

A mixture of two enzymes was used in the bio-scouring of raw jute. Cellulase enzyme (Texbio M, 2% owf), xylanase enzyme (Texeyme J, 2% owf) and non-ionic surfactant (Ultravon JU, 2 g/l) were used at 50 ^{0}C for 2 h. at liquor ratio 1:10 at pH 7-9. After that the temperature was raised to 90 ^{0}C for 15 min. then the fabric was washed with cold water thoroughly, then dried. Cellulase enzyme acts on cellulosic part of the fibre and xylanase enzyme acts on the hemi-cellulosic part of the fibre, this cumulative action of enzymes leads to 1.0% loss of jute fabric weight by removing a part of cellulosic and hemi-cellulosic portion.[15]

Bleaching of Jute Fabrics

Bleaching scoured jute fabrics were carried out in a closed vessel for 90 min at 80-85 °C, at a liquor ratio 1:20 with hydrogen peroxide (20 mL/L), Ultravon JU (2 mL/L), trisodium phosphate (5 g/L), sodium hydroxide (1 g/L), and sodium silicate (10 g/L), at PH 10. Then the fabric were washed in cold water thoroughly, then neutralized with acetic acid (2 mL/L) and washed again in cold water, then finally dried. Jute fabric loss about 4.6% of its weight after bleaching process.[14, 15]

Bio-mordanting of Jute Fabrics

Mordanting is essential for fixation of natural dyes in most cases.[2] Pomegranate was used as a natural source of mordant. (5% on weight of fabric) of pomegranate rind was soaked for 16 h, then boiled for 2 h using a 1:10 LR. Carbonate buffer (pH 10) was selected as extraction medium. The extraction temperature was 80 °C. For mordanting, jute fabric was treated in the extracted solution for one hour at 80 °C using a 1:20 LR after dilution with water. Then the fabric was dried without washing to prepare it for bleached jute fabric dyeing or second mordanting with ferrous sulfate/ potash alum.[14]..

Dyeing and Printing of Jute Fabrics with Natural Dyes

Extraction of Natural Dyes

Ratanjot, manjistha, annatto and babool respective parts were dried and ground to powder, then soaked in water for 12 h at three different pH conditions (alkaline, neutral, and acidic). After that the dye solution was boiled for 1 h. Then the extracts were cooled and filtered to remove the insoluble residues. The resulting filtrate was then used as a stock dye solution for subsequent dyeing experiments, and for printing, the solutions were dried in hot sand bath by evaporative drying process to produce dry dye powder.[13-15]

Dyeing of Jute Fabrics

Scoured, bleached and pre-mordanted jute fabric samples were dyed with natural dyes extracted under different pH conditions. Water was added to the extracted solution of colour from natural dyes (30% owm) to adjust the liquor ratio at 1:20. Alkaline pH 9–10 was maintained for ratanjot, neutral pH 7 for manjistha and babool, and for annatto, alkaline (pH 9–10) conditions were carried out for the first half of the dyeing then acidic (pH 4–5) conditions were carried out for the second half of the dyeing process.Jute fabric was entered in the dyebath containing (10 g/L) of Glauber's salt for 90 min at 80-90 °C. Then the dyed fabrics were washed in cold water thoroughly and then soaped with non-ionic surface active agent of (2 mL/L) for 30 min at 50 °C, followed by usual washing and drying process.[14] Bio-mordanting resulted in improvement of uniformity and levelness of dyed jute fabric using natural dyes extracted from annatto, manjistha, ratanjot and babool. Mordanting produced high K/S values after dyeing process with natural dyes as it achieved good wash, light and rubbing fastness properties.[14]

Printing of Jute Fabrics

A solution of (10%) from guar gum was boiled for 15-20 min and then kept at room temperature to bring down the solution to normal temperature. Then (4%) of natural dye powder and (4%) of urea were added to the thickener paste and stirred well, thus, printing paste was prepared. Printing was carried out using the flat screen technique with mesh size of 20 or 40. Printed samples were then dried and steamed at 100 0C for 30 min. Then the printed samples were washed with cold water for 20 min, followed by soaping with non-ionic detergent (2 g/L) for 10 min at 40 0C, Then fabrics were washed with cold water and dried in air.[13, 15] It is observed that the colour yield of the printed samples improves appreciably in terms of K/S value in case of mordanted fabric. This may be due to the interaction of natural dyes with mordant, resulting in improvement in colour strength and fixation onto the fabric giving good wash and rubbing fastness properties[13, 15].

Table 2: Color yield and fastness properties

Color yield and fastness properties of different printed jute fabrics using natural dyes

Dye	*K/S*	Wash fastness	Rub fastness	
			Dry	Wet
Manjistha	11.14	2 - 3	4 - 5	3 - 4
Annatto	10.3	2 - 3	5	4
Ratanjot	7.09	2 - 3	4 - 5	3 – 4

Conclusion

Jute is a significant cellulosic fabric that may be dyed and printed using a wide variety of dyes. Natural dyes have been used to dye and print jute fabrics with remarkable results in terms of fastness to rubbing, light, and washing, in addition to being eco-friendly and harmless.

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Conflict of Interest

The authors declared no competing interests in the publication of this article

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اتجاه صديق للبيئة لنسيج الجوت في العمليات الرطبة لتصنيع المنسوجات

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[3] *المركز القومي للبحوث (**Scopus 60014618**) ، معهد بحوث وتكنولوجيا النسيج ، قسم التحضيرات والتجهيزات للألياف السليلوزية، 33 شارع الحوث (شارع التحرير سابقا)، الدقي، ص.ب. 12622، الجيزة، مصر*

المستخلص

اليوت الذي يعرف بالألياف الذهبية الهندية هو ألياف لحائية طبيعية ذات بريق حريري، وقوة شد عالية، وقابلية تمدد منخفضة، ومظهر جمالي جيد. يُعرف الجوت كيميائيًا باسم ألياف الليجنو السليلوزية، وهو قابل للتحلل الحيوي ومتوفر بكميات كبيرة بسعر منخفض ويستخدم تقليديًا كمواد تعبئة وتغليف وبطانة للسجاد والحبال والحبال، ولكن نظرًا لطبيعة هذه الألياف الصديقة للبيئة اليوم لا يُنظر إلى الجوت على أنه ألياف نسيج رئيسية مناسبة للتعبئة فحسب، بل يستخدم أيضًا في صنع منتجات متنوعة وذات قيمة مضافة بما في ذلك المفروشات ومنسوجات الأثاث وحتى المنسوجات القابلة للارتداء حيث يتم استخدامه كمادة خام لتصنيع المنسوجات المصبوغة والمطبوعة ذات القيمة العالية. تحسن كبير في إنتاجية اللون، ومستوى الأصباغ، وخصائص ثبات نسيج الجوت. تهدف المراجعة الحالية إلى تسليط الضوء على المخاوف والتحديات التي تمت مواجهتها أثناء تطوير الجوت من مواد التعبئة والتغليف إلى نسيج نسيجي ذو خصائص امتصاص محسنة يمكن صبغه أو طباعته بأنواع مختلفة من الأصباغ الطبيعية والاصطناعية عن طريق تعديلات بسيطة وفعالة من حيث التكلفة باستخدام المصادر الطبيعية.

الكلمات المفتاحية: الجوت، الصديق للبيئة، الأصباغ الطبيعية، الصباغة، الطباعة.