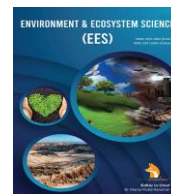




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RESEARCH ARTICLE

JUTE AS AN IMPACTFUL SUBSTITUTE TO PLASTIC PRODUCTS FOR ENVIRONMENTAL CONSERVATION AND SUSTAINABILITY

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ABSTRACT

This review paper provides a critical examination of the environmental impacts and performance characteristics of both plastic and jute products, utilizing extensive literature and empirical data. The comparative analysis of plastic and jute products reveals significant differences in their environmental impacts, underscoring the urgent need for sustainable alternatives to plastic. Plastic products contribute extensively to environmental pollution through improper disposal and long-lasting presence in ecosystems, contaminating rivers and oceans, and posing severe threats to wildlife and human health due to entanglement, ingestion, and the leaching of harmful chemicals. Plastic production and decomposition release substantial greenhouse gases, exacerbating global warming and climate change, with plastic production demanding 63 GJ/ton of energy and generating 1340 tons of CO₂ equivalent per ton produced. Conversely, jute products are celebrated for their biodegradability and sustainable sourcing. With a rapid growth cycle of 4-6 months and high cellulose yield, jute products decompose naturally, enriching the soil and reducing pollution. Although jute's heavier weight can lead to higher transportation emissions, its benefits in terms of renewability, composability, and minimal carbon footprint make it a superior alternative, with jute production requiring only 2 GJ/ton of energy and emitting a negligible 0.15 tons of CO₂ equivalent per ton produced. The historical significance and current trends of the jute industry in Bangladesh further underscore its potential as a sustainable resource, with the sector generating nearly \$1 billion annually. The mechanical properties of jute, such as tensile strengths ranging from 12.69 MPa to 112.69 MPa and tensile moduli up to 39.1 GPa, combined with its physical properties like strong seam strength and resistance to temperature variations, enhance its versatility across various applications. The transition to jute products can significantly mitigate the adverse impacts of plastic pollution, promoting environmental conservation and sustainable industry practices.

KEYWORDS

Environmental Impacts, Jute Products, Plastic Substitution, Sustainability, Future Prospects.

1. INTRODUCTION

The advent of plastics marked a pivotal moment in human history, significantly enhancing living conditions. Their lightweight, durability, resistance to most chemicals, diverse applications, ease of processing, and cost-effectiveness have led to plastics replacing numerous materials like wood, metals, and ceramics in consumer goods production since their initial synthesis in the early 1900s. Beyond these advantages, research indicates that plastic-based products have lowered production costs across various industries, facilitated product diversification, and driven global market growth, particularly in the packaging sector. This growth has resulted in increased profits for chemical, oil, and manufacturing companies (Sartorius, 2010; Dauvergne, 2018).

Plastics are synthetic polymeric materials primarily created from petrochemicals. Common polymers produced from petrochemicals include polyester, polyethylene, polypropylene, polyethylene terephthalate (PET), polyvinyl chloride (PVC), and polystyrene (Nanda et al., 2022; Geyer et al., 2017). Plastics have become integral to commerce, household goods, and various industries, playing a crucial role in modern

civilization. Factors such as population growth, economic expansion, commodity demand, and lifestyle changes drive the global demand for plastic products (Nanda et al., 2022). Their lightweight, flexibility, tensile strength, low production cost, and wide availability make plastics suitable for a myriad of applications. In packaging, plastics have surpassed glass and paper in prevalence (Nanda et al., 2022; Shafqat et al., 2020). From 2010 to 2020, global plastic production increased by 36%. Researchers report that the annual generation of plastic waste is nearing 150 million tons worldwide. Currently, the world produces approximately 8300 million metric tons of new plastic annually (Thakur and Thakur, 2016). Of the 6300 Mt of plastic waste generated each year, only 9% is recycled, 12% is incinerated, and the remaining 79% is discarded in landfills or the environment. If current trends continue, it is estimated that 12,000 Mt of residual plastic will accumulate in landfills or the environment by 2050 (Geyer et al., 2017). The environmental impact is significant, with plastic waste polluting soil, water, oceans, and landfills, endangering humans, animals, and plants. Plastic pollution has resulted in the deaths of 100,000 marine species and over a million seabirds globally (Othman et al., 2021). Additionally, plastic production is energy-intensive, contributing to a substantial carbon footprint and associated environmental concerns due to the fragmentation of petroleum-derived plastics. Due to the non-

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renewable nature of crude oil and its rising costs, scientists and researchers are actively seeking practical alternatives to plastics (Ismail et al., 2016). Jute, a natural fabric, presents a promising option as it is robust, biodegradable, compostable, highly resilient, recyclable, and has a low carbon footprint. Notably, jute plants release more oxygen and consume less carbon dioxide (CO₂) than trees, thereby reducing the greenhouse effect and helping to maintain ecological balance (Pavel and Supinit, 2017; Singh, 2017). Jute products also require less energy and have a lower carbon footprint compared to conventional plastic items (Singh et al., 2018). Many commonly used plastic products, such as shopping bags, rice bags, plastic ropes, and file folders, can be effectively replaced by jute alternatives. These jute products boast superior mechanical and biodegradable properties, a reduced carbon footprint, and do not pose risks to humans, animals, or the environment (Singh, 2017; Saha and Sagorika, 2013). This study provides a comprehensive overview of the chemical and physical properties of both plastic and jute, as well as their environmental impacts. Additionally, it explores the social and economic factors, along with the challenges to achieving sustainability goals, and suggests a few carefully selected sustainable alternatives to plastic technologies.

2. STUDY METHOD

All data for this review were sourced from Google Scholar, ResearchGate, government websites, web links, Springer Link, online journals, and policy papers. To ensure the relevance and accuracy of the information, data spanning the last 20 years (2002–2022) were utilized for this study. From a comprehensive review of approximately 46 articles, 20 were selected for citation based on their pertinence and contribution to the subject. The study examines the behaviors and environmental impacts of jute and plastic products, providing scientifically valuable insights. These findings are expected to be highly beneficial to academics, government agencies, and non-governmental organizations globally. Additionally, the comprehensive analysis presented in this review aims to inform policy development and promote sustainable practices within the industry.

3. RESULTS AND DISCUSSION

This review paper is organized into nine sections, each addressing specific aspects of the subject matter as follows: the physical and chemical properties of plastics (3.2), the manufacturing rates of plastics (3.1), and the environmental impact of plastic products (3.3). Subsequent sections explore the history of the jute industry in Bangladesh (3.4), current trends in the country's jute industries (3.5), properties of jute products (3.6), and the environmental impact of jute products (3.7). The paper also includes a comparative analysis of jute and plastic products (3.8), examines the

future prospects of both jute and plastic products (3.9), and concludes with a summary of the findings.

3.1 Physical and chemical behaviors of plastic

Plastics, also known as synthetic polymers, have been mass-produced for roughly 70 years, yet their usage has outpaced that of most other man-made materials. Modern plastics can be broadly categorized into seven types. Table 1 provides a comprehensive overview of various plastic types, their applications, physical properties, and associated health risks. This table outlines the usage, decomposition time, physical characteristics, leached toxins, safety status, and tensile strength of different plastic polymers. Moreover, polyethylene terephthalate (PETE), commonly found in bottles, ropes, and tote bags, is noted for its high heat resistance and toughness. However, it is considered unsafe due to the leaching of carcinogenic antimony. High-density polyethylene (HDPE), frequently used in milk jugs and detergent bottles, offers excellent chemical resistance and strength but poses risks due to the presence of estrogen-mimicking chemicals, as highlighted by (Dhara et al., 2024). Low-density polyethylene (LDPE), employed in plastic wrap and garbage bags, is known for its flexibility but shares similar concerns regarding hormonal disruption as HDPE. Polyvinyl chloride (PVC), utilized in plumbing and credit cards, is durable but leaches hazardous compounds such as BPA and phthalates, rendering it unsafe. Polypropylene (PP), found in yogurt containers and car parts, boasts good chemical resistance but can leach chemicals that may lead to health issues. Polystyrene (PS), used in plastic cutlery and foam cups, is highly toxic and leaches styrene, a carcinogenic compound detrimental to human health.

This analysis underscores the trade-offs between the desirable physical properties of plastic polymers and their adverse environmental and health impacts. The harmful effects of these materials, ranging from hormone disruption to carcinogenic risks, highlight the urgent need for a shift towards safer and more sustainable material alternatives. The paper advocates for increased research and development in alternative materials that offer similar benefits without the associated health and environmental hazards. Additionally, it calls for stricter regulations and more comprehensive recycling and waste management strategies to mitigate the impact of plastic pollution. By presenting a detailed examination of the characteristics and risks associated with various plastics, this study aims to raise awareness about the hidden costs of synthetic polymers and promote the adoption of greener alternatives. The transition towards sustainable materials is essential for reducing environmental degradation and safeguarding public health, emphasizing the importance of integrating sustainability into material production and consumption patterns.

Table 1: Various plastic types and their usage, physical properties, and associated health challenges

Plastic Polymers	Time to Decompose (years)	Physical Properties	Leached Toxins	Associated Health Challenges	Status	References
PETE	10	Clear, strong, lightweight, recyclable	Antimony (Carcinogenic)	Can release antimony and phthalates, potential carcinogen concerns	Not safe	(Achillas et al., 2008)
HDPE	100	Rigid or flexible, resistant to chemicals and moisture	estrogen-mimicking chemicals (disrupting hormones)	Generally considered safe, potential for endocrine disruption if additives are used	Usually, safe and low risk	(J. Akhtar, and Amin, 2011)
LDPE	500-1000	Flexible, transparent, strong, resistant to moisture	estrogen-mimicking chemicals, the same as HDPE	Generally considered safe, can release toxic chemicals during production	safe	(Bhattacharyya et al., 2019)
PVC	never	Rigid or flexible, resistant to chemicals and moisture	BPA, phthalates, lead, mercury	Releases vinyl chloride, a known carcinogen, and phthalates, which are endocrine disruptors	Not safe	(Bhattacharyya et al., 2019)
PP	20-30	Tough, resistant to heat, chemical resistant, lightweight	leaching some chemicals leading to asthma or hormone disruption	Generally considered safe, concerns about additives like phthalates	Micro-wave safe	(Verma et al., 2016)
PS	50	Rigid, brittle, can be foamed, lightweight	highly toxic, leaching styrene can cause cancer and damage to the nervous system, affect genes	Can leach styrene, a possible human carcinogen, especially when heated	Not safe	(Zhou et al., 2016)

Plastics, a diverse group of synthetic materials primarily derived from petrochemicals, possess unique chemical structures and properties. Figure 3 illustrates the biological formulas of various plastic types.

Polyethylene (PE), one of the most prevalent forms, has the chemical formula (C₂H₄)_n, where 'n' indicates the number of repeating ethylene units. Among the seven categories of plastics, LDPE generates the most

waste at 7.4 billion kg, while PVC has the lowest production volume at 0.9 billion kg. Polypropylene (PP), produced at approximately 7.2 billion kg, is the second most common plastic. Its recycling rate stands at 5.3%, and its general formula is $(C_3H_6)_n$. Due to their relatively moderate decomposition rates, PET and PETE boast a maximum recycling rate of 19.5%. On the other hand, PVC never degrades, resulting in a 0% recycling rate. Polyethylene comes in various densities, such as high-density polyethylene (HDPE) and low-density polyethylene (LDPE) and is used in products ranging from plastic bags to bottles. Polyvinyl chloride (PVC), characterized by the formula $(C_2H_3Cl)_n$, includes chlorine atoms that provide rigidity and resistance to chemical and biological degradation. This makes PVC suitable for construction materials, piping, and medical devices. Polypropylene (PP), with the formula $(C_3H_6)_n$, is known for its strength and resistance to chemical solvents, acids, and bases, making it ideal for packaging, textiles, and automotive parts. Polystyrene (PS), with

the formula $(C_8H_8)_n$, is a versatile plastic recognized for its rigidity and ease of molding, used in products from disposable cutlery to insulation materials. Polyamides (PA), commonly referred to as nylon, have the general formula $(C_6H_{11}NO)_n$ and are distinguished by amide groups that provide high mechanical strength and thermal resistance, suitable for textiles, automotive, and industrial applications. Polyethylene terephthalate (PET), with the formula $(C_{10}H_8O_4)_n$, is a strong, lightweight plastic extensively used in food and beverage packaging, especially for bottles and containers. Each type of plastic, with its distinct molecular structure, presents unique recycling challenges and environmental impacts. Addressing these challenges requires targeted waste management and recycling strategies to mitigate their effects on the environment. Understanding the chemical composition and properties of these plastics is essential for developing effective recycling processes and reducing plastic pollution.

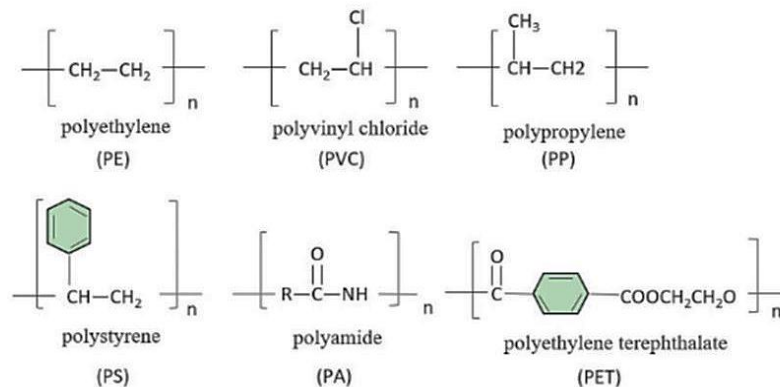


Figure 1: Chemical formula of various types of plastic waste

3.2 Effect of plastic products on the environment

Plastic indisputably poses severe environmental threats, primarily due to its pervasive pollution. Firstly, their widespread use contributes significantly to environmental pollution. Improper disposal of plastic items, whether through littering or inadequate waste management, leads to their accumulation in natural habitats, including oceans, rivers, and terrestrial ecosystems. This pollution poses a direct threat to wildlife, as animals often mistake plastic debris for food or become entangled in it, leading to injuries, suffocation, and death. Improper disposal of plastic waste can contaminate rivers and oceans, endangering marine ecosystems. Unlike biodegradable organic waste such as fecal sludge and microalgae, plastic persists for centuries in landfills, exacerbating environmental degradation (Khalekuzzaman et al., 2023). Furthermore, the production of plastic contributes significantly to deforestation and exacerbates global warming through the release of greenhouse gases (Dhara et al., 2024; Hasan et al., 2023). This cumulative effect intensifies the global climate crisis, impacting both human populations and biodiversity (Alsabri et al., 2022). Moreover, the production and disposal of plastic products contribute to greenhouse gas emissions and exacerbate global warming. The manufacturing process releases carbon dioxide and other greenhouse gases, while plastic waste in landfills emits methane as it decomposes, further intensifying climate change. Additionally, plastic pollution can lead to habitat degradation and alter ecosystems, impacting biodiversity and ecosystem services.

In terms of human health, plastic poses risk due to its propensity to leach harmful chemicals into food and water supplies, potentially leading to serious health conditions such as cancer and reproductive disorders. Additionally, plastic debris such as 6-pack rings and fishing lines pose physical hazards to wildlife, entangling and injuring or even killing animals. Furthermore, ingestion of plastic by animals, especially sea turtles mistaking it for jellyfish, can result in fatal intestinal blockages or starvation (Pinto Costa et al., 2020). These cumulative impacts underscore the urgent need for sustainable solutions to mitigate plastic pollution and its far-reaching consequences on ecosystems and human health alike.

3.3 History of the Jute Industry in Bangladesh

Historically, jute was used in Bengali handlooms to produce rope and garments. In 1838, Dundee Mills received a request from the Dutch-controlled Java sugar fields for jute bags. Following the techniques of the Melville and Balfour companies, they manufactured burlap bags from jute, which saw significant demand and helped promote Bengal's jute. In 1855,

George Auckland established the first jute factory near Rishra. In 1873, the British Raj formed a commission to investigate Bangladesh's jute industry and farming practices, leading to the publication of the "Jute Trade and Cultivation in Bengal" report in 1877 (Akter et al., 2020).

Moreover, during British India, Kolkata became the center of the jute trade. While jute was produced in East Bengal, all 108 jute mills were situated in West Bengal. The partition of India presented challenges to jute production. By 1970, East Pakistan (now Bangladesh) had seventy-seven jute mills employing approximately 170,000 people. In 1951, three significant companies were established in East Bengal: Adamjee Jute Mill, Bawa Jute Mills Ltd., and Victory Jute Products Ltd. Adamjee Jute Mills was built with financial assistance from the Pakistan Industrial Development Corporation. By 1960, the number of operational jute mills had increased to 14. In the post-partition era, the jute industry continued to evolve. The jute mills in East Bengal became vital to the economy, fostering employment and contributing significantly to exports. Over time, technological advancements and governmental support played crucial roles in sustaining the industry. Today, the legacy of jute production in Bangladesh highlights its historical importance and its potential as a sustainable resource in the global market. The industry's resilience through political changes and economic challenges underscores the enduring significance of jute in the region's industrial landscape.

3.4 Trends of current jute industries in Bangladesh

Jute pricing, procurement, and trading in Bengal are regulated by the Bangladesh Jute Mills Corporation (BJMC). The government established the Jute Division in 1973, which was part of the Department of Treasury. In 1979, a legislative commission recommended the privatization of the jute factories. Consequently, between 1979 and 1980, two jute mills were privatized, and three were returned to their original owners (Abdullah, 2017). The jute sector significantly contributes to Bangladesh's economy, generating nearly \$1 billion annually (Bell and Cave, 2011). In January 2018, the government implemented a ban on the export of raw or unprocessed jute. However, this restriction was lifted in June 2019 following a request from the Bangladesh Jute Association. The regulation and management of jute by the BJMC play a crucial role in stabilizing the industry. Despite facing challenges such as fluctuating market demands and competition from synthetic alternatives, the sector has shown resilience. The privatization efforts in the late 1970s aimed to increase efficiency and profitability within the industry. The temporary ban on raw jute exports in 2018 was intended to encourage the domestic processing of jute, thereby adding value and creating more jobs within Bangladesh.

The subsequent lifting of the ban in 2019 was likely due to pressures from stakeholders who were affected by the restrictions, demonstrating the complex balance between domestic industrial policy and international trade dynamics.

3.5 Properties of jute products

The mechanical properties of various jute-based materials are detailed in Table 2. This comparative analysis highlights their potential as reinforcement components in composite applications. Extracted from diverse studies, the data reveals significant variations in tensile strength, modulus, flexural strength, and impact resistance among different jute compositions. For instance, bidirectional jute fiber mats exhibit a tensile strength of 110 MPa and a tensile modulus of 4.45 GPa, alongside a flexural strength of 55.8 MPa and a flexural modulus of 3.02 GPa. Woven jute configurations demonstrate moderate tensile and flexural properties, with tensile strengths ranging from 12.69 MPa to 15.53 MPa and flexural strengths from 79.20 MPa to 81.81 MPa. Jute laminates display high tensile strength and modulus values along the longitudinal axis, achieving a tensile strength of 112.69 MPa and a tensile modulus of 39.1 GPa. Jute mats

offer reasonable tensile strength and modulus values, with a tensile strength of 42.0 MPa and a tensile modulus of 1.61 GPa.

Overall, these findings underscore the versatility of jute as a reinforcement material, with significant potential for use in diverse industries. Further optimization and research into manufacturing processes and treatment methods are necessary to enhance mechanical performance and expand application horizons. In contrast, the durability of plastics presents a persistent environmental challenge. Unlike organic materials, plastics degrade very slowly, persisting in the environment for hundreds of years. This longevity means that even small plastic items, such as microplastics, can accumulate over time and spread throughout ecosystems. As these microplastics potentially enter the food chain, they pose risks to human health and disrupt natural processes. Given these contrasting properties, the promotion of jute as a sustainable alternative to plastic is imperative. The mechanical properties of jute make it suitable for various applications, and its biodegradability offers significant environmental benefits. The transition towards using more jute-based materials could mitigate the adverse impacts of plastic pollution, fostering a healthier environment and promoting sustainable industry practices.

Table 2: Mechanical Properties of Jute Fiber

Reinforcement	Tensile Strength (MPa)	Tensile Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Impact Strength	References
Bidirectional jute fibre mat	110	4.450	55.80	3.02	4.87	(Mishra et al., 2013)
Jute	69.66	6.19	94.08	5.91	-	(Seki et al., 2009)
Woven jute	15.53	0.2554	79.20	1.355	0.28J	(Owen et al., 2014)
Woven jute	12.69	0.1985	81.81	1.381	0.35J	(Owen et al., 2014)
Jute laminate (Longitudinal 0-0)	112.69 39.1	14.59	-	-	-	(Hossain et al., 2013)
Jute laminate (Transverse 0-90)	39.1	8.97	-	-	-	(Hossain et al., 2013)
Jute	16.62	0.667	57.22	8.956	13.44kJ/m ²	(Bhoopalan et al., 2013)
Jute	26.53	6.32	66.67	5.78	80J/m ²	(Venkatesh waran et al., 2012)
Jute	60	7	92.5	5.1	29 KJ/m ²	(Gowda et al., 1999)
Jute	48.52	4.23	63.01	3.62	-	(Seki et al., 2009)
Jute	77.1	5.07	176	19.26	24.7KJ/m ²	(Shanmugam et al., 2013)
Long jute (Longitudinal)	162	5.58	-	-	1295J/m	(Crosky et al., 2014)
Long jute (Transverse)	0.43	0.98	-	-	148J/m	(Crosky et al., 2014)
Jute mat	23.0	4.0	-	-	-	(Hojo et al., 2014)
Jute	-	-	199.1	11.890	22.10	(Ray et al., 2001)
Jute mat	42.0	1.61	56.2	3.78	-	(Crosky et al., 2014)

Table 3 provides a comprehensive assessment of the physical properties associated with natural jute fibers. Known for their smooth texture and distinctive golden shine, jute fibers are aesthetically appealing. They possess strong seam strength, ensuring durability across different uses, and are resistant to sunlight and temperature variations, making them versatile in diverse environments. Jute is particularly effective for grain preservation and stack stability in agriculture. It is biodegradable and

environmentally friendly, aligning with sustainability efforts, with jute plants replenishing in 4-6 months and yielding ample cellulose. Despite being heavy, jute fibers offer good dimensional stability and can be reused effectively. However, their higher cost reflects their premium quality and limited availability. Jute surfaces are typically rough, which may affect specific applications, yet they excel in optimizing storage space, making them practical for various storage solutions.

Table 3: Physical Properties of Jute

S.N.	Properties	Remarks
01	Natural fiber	smooth and golden sheen
02	Seam Strength	Strong
02	Sunlight and ambient temperature effects	unaffected
04	Efficiency for grain preservation	Excellent
05	Stack Stability	Outstanding
06	Biodegradability	Completely
07	Environmentally	friendly
08	Jute stem can supply the need for wood	4-6 months
09	Cellulose that obtained	very large amount
10	Weight	Heavy
11	Dimensional stability	Good
12	Reusability	Excellent
13	Cost	expensive
14	Surface Texture	Rough
15	Storage space utilization	Excellent

3.6 Effects of jute products on the environment

Jute products are celebrated for their environmentally friendly qualities, notably their biodegradability and sustainable sourcing. Jute is highly biodegradable, ensuring that products made from it break down naturally without causing lasting environmental harm. Its renewable nature, with a quick growth cycle of 4-6 months and a high yield of cellulose, positions it as a viable sustainable alternative to traditional materials. However, there are challenges to consider, such as the considerable weight of jute products, which can contribute to higher transportation emissions and energy consumption. Despite these concerns, jute excels in stack stability and effectiveness in preserving grains, highlighting its utility in agricultural contexts. While jute's rough texture and relatively higher cost may limit its widespread adoption, it offers significant advantages such as maximizing storage space efficiency and demonstrating strong seam strength. These qualities underscore its versatility and potential for various applications. In conclusion, while there are trade-offs associated with using jute, its eco-friendly attributes and versatile properties make it a compelling choice for sustainable practices and applications in diverse industries.

When comparing environmental impact, natural fibers such as jute offer substantial advantages over synthetic alternatives. Beyond their direct ecological benefits, these fibers also play a crucial role in shaping economic dynamics. Jute's green leaves are not only harvested for vegetable production but also contribute to the soil's fertility when they dry out. Additionally, the leaves and roots of the jute plant serve dual purposes as natural insecticides and soil enhancers, respectively. The utilization of jute in particle and composite materials reduces the reliance on wood as a fuel source, thereby alleviating pressures on forestry resources. This practice aligns with environmentalists' recommendations for nations to maintain forested areas at least 25% larger than current levels; however, many countries fall significantly short, with rates hovering around 8% to 9%. Jute's rapid growth cycle presents a viable solution to help bridge this gap, absorbing carbon dioxide from the atmosphere and contributing to the preservation of the ozone layer. Moreover, jute plants release oxygen into the atmosphere, crucial for human survival. Beyond their environmental and economic benefits, jute plants also enrich the soil with essential nutrients and act as natural air filters, improving air quality. These

multifaceted contributions underscore jute's significance not only in sustainable agriculture and industry but also in mitigating environmental challenges on a global scale (Islam and Ahmed, 2012).

3.7 Comparison of plastic and jute products

Table 4 highlights significant disparities between jute and plastic products in terms of their environmental impact and performance characteristics. Jute stands out as a biodegradable and renewable material, providing a sustainable alternative to non-biodegradable and finite plastic products. This distinction is further underscored by the carbon footprint, where jute products exhibit minimal environmental impact compared to the high carbon footprint associated with plastics. Additionally, jute products are compostable, contributing to waste reduction and environmental conservation, a feature that plastic products lack. Jute's resilience to atmospheric temperature changes contrasts sharply with the vulnerability of plastic to such variations, emphasizing its environmental durability. In terms of performance, jute products generally demonstrate reliable attributes such as excellent stack stability and moderate resistance to snagging, whereas plastic products typically fall short in these aspects.

In terms of performance characteristics, jute's excellent stack stability and moderate resistance to snagging make it a practical choice for various applications. Its ability to withstand temperature fluctuations without degrading ensures durability in diverse environmental conditions. Plastic products, on the other hand, often suffer from reduced performance under similar conditions, leading to increased waste and environmental harm. By adopting jute over plastic, industries can contribute to a circular economy, where materials are reused and recycled, reducing the need for virgin resources and lowering greenhouse gas emissions. This shift is vital for achieving sustainability goals and ensuring a healthier planet for future generations. As awareness of the environmental impacts of plastic grows, the demand for sustainable alternatives like jute is expected to rise, driving innovation and investment in eco-friendly materials. Overall, the comparative analysis in Table 6 underscores the need for a transition towards jute products to mitigate environmental impact and promote ecological stewardship. The superior environmental and performance characteristics of jute make it a viable alternative to plastic, supporting efforts to achieve a more sustainable and resilient future.

Table 4: Comparative performance of jute and plastic products

Properties	Jute products	Plastic products
Biodegradability	Biodegradable	Not Biodegradable
Renewability	Renewable	Not renewable
Carbon footprint	Very low Carbon footprint	Very high Carbon footprint
Composability	Compostable	Not compostable
Effect of atmospheric temp.	Unaffected	Highly affected
End-used performance	Good	Poor
Stack stability	Excellent	Poor
Resistance for hooking	Fair	Poor

Additionally, the comprehensive analysis presented in Table 5 highlights not only the stark contrast in energy consumption between plastic and jute products but also the significant implications for their respective carbon footprints. Plastic production demands a substantial 63 GJ/ton of energy, in stark contrast to the minimal 2 GJ/ton required for jute products. This disparity directly translates into environmental impact, with plastic generating a staggering 1340 tons of CO₂ equivalent per ton produced, while jute emits a negligible 0.15 tons of CO₂ equivalent. These findings underscore the unsustainable nature of plastic manufacturing, marked by its heavy reliance on energy-intensive processes and the consequent large-scale emissions contributing to climate change. In contrast, jute emerges

as a far more environmentally friendly option, requiring vastly less energy and producing minimal greenhouse gas emissions. This highlights the urgent need to shift towards sustainable materials like jute to mitigate the detrimental effects of climate change and environmental degradation caused by conventional plastic production. By embracing materials with lower energy requirements and reduced carbon footprints, such as jute, industries and consumers alike can play a pivotal role in fostering a more sustainable future. This transition not only promotes environmental stewardship but also supports the development of eco-friendly practices that safeguard natural resources and enhance global resilience to climate change impacts. (Saha and Sagorika, 2013)

Table 5: Energy input and carbon footprint output for plastic and jute products

Products	Energy (GJ/Ton)	Carbon footprint, (Tons CO ₂ eq.)
Plastic	63	1340
Jute	02	0.15

3.8 Future prospects of jute and plastic products

Plastic poses numerous detrimental environmental impacts, from contaminating waterways to endangering marine biodiversity. Ignoring this issue is no longer an option; urgent action is necessary to reduce our dependence on plastic. Simple changes in daily routines, such as using reusable bags and water bottles, can initiate meaningful progress

(Srivastava, 2012). By uniting efforts, even though modest actions, we can drive substantial change. Global and regional studies consistently highlight Bangladesh's vulnerability to plastic pollution, underscoring the urgent need for immediate intervention. Despite limited research on the scale, fate, and environmental impact of plastic waste in Bangladesh, it is evident that pollution affects all ecosystems, threatening both human well-being and marine life. Achieving the United Nations' 2015 sustainable

development goal of a clean, prosperous planet by 2030 hinges on effective oversight of plastic production and waste management (Green Marketing of Jute and Jute Products: A Study on Bangladesh, 2015). While Bangladesh has taken initial steps to address this issue, the expected reduction in plastic use and pollution has not materialized. Therefore, sustainable solutions must be prioritized. It is imperative to implement comprehensive measures to combat this global challenge effectively. Consequently, it is advised that the following steps be taken in order to address this global issue sustainably:

- Utilizing media campaigns and initiatives led by governmental and non-governmental organizations to educate consumers about the harmful impacts of plastic usage and encourage them to opt for alternatives.
- Implementing incentive-based programs in areas where plastic collection initiatives are in place to discourage improper disposal and promote responsible waste management practices.
- Strengthening collaborations between universities and research institutions to comprehensively assess the environmental impacts of plastic waste across various domains.
- Increasing investment in research and development for biodegradable polymers and economically viable alternatives to traditional plastic, especially in packaging materials.
- Providing financial incentives such as simplified bank financing, duty-free imports of equipment, and preferential tax treatment to businesses involved in developing biodegradable plastic alternatives.
- Leveraging Bangladesh's substantial jute production capacity to manufacture affordable biodegradable alternatives to plastics, and offering incentives to companies engaged in this sector.
- Introducing significant tariffs on plastic-related industries, from raw material imports to final product sales, to discourage their use and promote environmentally friendly alternatives.
- Promoting environmentally sustainable practices in plastic production and recycling industries as long-term solutions to address unemployment issues in the country.
- Conducting further research to identify cost-effective methods for producing and marketing jute products, ensuring their availability and accessibility to consumers.

4. CONCLUSION

As global populations grow and economies expand, the pervasive use of plastic has become entrenched across various sectors, including industry, commerce, and household applications. Yet, the enduring non-biodegradability of plastics poses severe risks to human health, ecosystems, and wildlife, impacting both terrestrial and aquatic environments. Plastics contribute significantly to environmental pollution, requiring 63 GJ/ton of energy for production and resulting in 1340 tons of CO₂ equivalent emissions per ton. In contrast, jute emerges as a transformative and eco-friendly alternative to petroleum-based plastics. Naturally sourced and inherently biodegradable, compostable, and reusable, jute stands out for its exceptional durability and minimal environmental footprint. It requires only 2 GJ/ton of energy for production and emits a negligible 0.15 tons of CO₂ equivalent per ton. Jute's ability to absorb carbon dioxide and release oxygen significantly contributes to greenhouse gas reduction and ecosystem stability. The mechanical properties of jute, such as tensile strengths between 12.69 MPa and 112.69 MPa, enhance its durability and extended usability, reducing the need for frequent replacements. While the heavier weight of jute products can lead to higher transportation emissions, the overall environmental benefits make it a viable and sustainable alternative. The transition from plastic to jute products requires comprehensive and collaborative action. Despite initial steps in Bangladesh to address plastic pollution, the expected reduction in plastic use has not yet materialized. Implementing robust measures, such as media campaigns, incentive-based programs, and increased investment in biodegradable alternatives, is crucial for driving sustainable change. Leveraging Bangladesh's substantial jute production capacity to manufacture affordable biodegradable options and promoting responsible consumption practices are key to mitigating plastic pollution. This transition is essential for advancing a greener economy, fostering environmental conservation, and promoting responsible consumption practices that underscore our commitment to sustainability.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Tasnim Tarannum Jarin: Conceptualization, Methodology, Resources, Formal analysis, Software, writing – original draft, writing – review, and editing; Md. Atik Fayshal: Conceptualization, Methodology, Resources, Formal analysis, Software, writing – original draft, writing – review, and editing.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY

Data will be made available on request

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