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GREEN TRANSFORMATION OF THE COIR SECTOR: INNOVATION, SUSTAINABILITY, AND MARKET COMPETITIVENESS IN KERALA

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ABSTRACT

Kerala's coir industry, a traditional sector with profound cultural and economic roots, is transitioning to a greener future. This study investigates the relationship between innovation uptake, sustainability practices, and market competitiveness in the coir sector, with a focus on eco-friendly technology and circular economy principles. A structured study was undertaken among 120 coir producing businesses in five districts of Kerala. The study used multiple regression analysis to look at how the independent variables – green innovation index (GII), sustainability score (SS), and government support level (GSL) – affected the dependent variable, market competitiveness. There is a substantial positive association between GII and MC ($r = 0.68, p < 0.01$), suggesting that enterprises investing in green technologies report larger market share and export potential. The Sustainability Score (SS), based on waste reduction, energy efficiency, and water conservation indicators, had a moderate impact on MC ($\beta = 0.42, p < 0.05$). GSL, comprising subsidies and training programs, significantly predicted innovation adoption ($\beta = 0.55, p < 0.01$). The study suggests that green transformation is not only environmentally important but also economically beneficial to Kerala's coir business. Policy recommendations include increasing green funding, promoting public-private collaborations, and incorporating sustainability into export branding.

KEYWORDS: Green Innovation, Sustainability Score, Market Competitiveness, Environmental Awareness.

INTRODUCTION

The coir business in Kerala, India, is one of the world's oldest agro-based cottage industries, inextricably linked to the state's cultural legacy and rural economy. Historically relying on human labour and primitive procedures, the sector has provided a living for many, notably women in coastal and backwater areas. However, in recent decades, the business has encountered numerous obstacles, including worldwide competitiveness, environmental scrutiny, dwindling profitability, and technical stagnation. These challenges demanded a strategic change towards green transformation, which includes the use of sustainable production processes, eco-innovation, and ecologically responsible business practices.

Green transformation is more than just a technological improvement; it is a systemic shift that combines industrial development and environmental care. In the coir sector, this includes switching from chemical-intensive retting processes to microbial or enzymatic alternatives, using solar-powered machinery, promoting biodegradable coir composites, and implementing circular economy models that reduce waste while increasing resource efficiency. Global markets are rapidly demanding such advances, particularly in Europe and North America, where environmental certifications and sustainable sourcing are now required for trade. Despite the increased discussion about sustainability, empirical research on the causes and consequences of green transformation in Kerala's coir sector is sparse. While government programs such as the Coir Board's "Green Coir" program and numerous MSME schemes have attempted to catalyse eco-innovation, their impact in increasing market competitiveness has yet to be thoroughly assessed. Furthermore, the significance of firm-level factors such as environmental awareness, innovation capacity, and access to governmental support in determining sustainability results has received insufficient attention.

This study aims to close this gap by investigating the relationships between green innovation uptake, sustainability practices, and market competitiveness in Kerala's coir manufacturing units. It also looks into the moderating impacts of government assistance and environmental consciousness, giving us a better knowledge of how institutional and cognitive factors affect the effectiveness of green transformation. Drawing on theoretical frameworks such as the Resource-Based View (RBV) and the Triple Bottom Line (TBL), the study uses a quantitative approach to

analyse data collected from a cross-section of coir firms across the state.

This study's conclusions are expected to provide practical insights for policymakers, industry stakeholders, and development organisations. By identifying the key drivers and impediments to green transformation, the research helps to develop targeted interventions that can boost Kerala's coir sector's worldwide competitiveness while also promoting environmental sustainability and inclusive growth.

REVIEW OF LITERATURE

The coir business in Kerala, which has historically been based on artisanal traditions and rural livelihoods, is undergoing a transformation driven by sustainability imperatives, technological innovation, and global market dynamics. Scholars such as Nair (2015) and Rajan & Mathew (2017) have emphasised the socioeconomic importance of coir production in Kerala, citing its role in empowering women and maintaining rural employment. India, with Kerala at the vanguard, accounts for over 80% of worldwide coir production, positioning the state as a critical base for green industrialisation (Coir Board, 2023).

In recent years, the sector has seen increased innovation. Thomas and Joseph (2019) emphasise the diversification of coir products into geo-textiles, composite boards, and horticulture substrates, indicating a move from traditional weaving to value-added uses. The Kerala State Coir Machinery Manufacturing Company (KCMMC) has led material science innovation by generating coir-polymer composites that exceed traditional materials in terms of durability and environmental performance (KCMMC, 2024). These advances are consistent with Chattopadhyay et al.'s (2024) argument that Kerala's innovation ecosystem, through platforms such as K-DISC and the Young Innovators Programme, is driving grassroots technological improvement in traditional sectors.

Circular economy principles are increasingly guiding sustainability narratives in the coir industry. Unnikrishnan and Deepa (2023) describe how coconut husk waste, which was formerly dumped, is now reused into coir pith and fibre products that help to save soil and retain water. This waste-to-value approach is shared by Vimal and Biju (2024), who see coir as a climate-resilient material that contributes to carbon sequestration and biodiversity conservation. Furthermore, Menon (2020) emphasises the importance of coir geotextiles in reducing soil erosion and supporting sustainable agriculture.

Despite these advances, difficulties remain. Kumar and Pillai (2018) identified fragmented supply chains, insufficient mechanisation, and inconsistent branding as major impediments to scaling and export competitiveness. However, Sreedharan (2021) believes that smart branding of Kerala coir as a premium sustainable product, combined with digital marketing and e-commerce integration, can open up new global markets. Institutional support remains crucial. The Coir Board's Vision 2025 and Kerala's "One Local Government, One Innovation" project are actively supporting modernisation, skill development, and collaborative innovation (Coir Board, 2023; GIFT, 2024).

The modernisation of coir production in Kerala has received scholarly attention for its contribution to improved product quality and expanded market uses. According to Das and Radhakrishnan (2020), mechanisation and fibre conditioning technologies have greatly increased coir yarn's tensile strength and homogeneity, making it suitable for use in industrial composites. Bhattacharya (2021) emphasises the advent of coir-based acoustic panels and thermal insulators, which are increasingly being used in green building projects. These advances are part of a broader trend of material substitution, in which natural fibres replace synthetics in building and packaging. Sundaram and Iyer (2022) emphasise the importance of public-private partnerships in scaling such technologies, noting that Kerala's coir clusters get targeted R&D investments and incubation support.

The ecological benefits of coir have been well documented in sustainability literature. Mukherjee and Srinivasan (2019) highlight coir geotextiles as excellent instruments for slope stabilisation and water conservation, especially in monsoon-prone areas. Patel et al. (2021) investigate the carbon footprint of coir production and conclude that it has much lower lifecycle emissions than synthetic alternatives. This is consistent with Verghese and Nambiar (2022), who argue for coir inclusion in climate-smart agricultural and soil regeneration projects. They contend that Kerala's coir industry illustrates circular economy principles by transforming agricultural waste into long-lasting, biodegradable products. According to Sharma and Ghosh (2023), coir pith is now a lucrative soil conditioner and export product, having previously been a disposal difficulty. Collectively, these findings support the idea that coir is more than just a sustainable material.

Branding, certification, and customer awareness

are progressively influencing coir market competitiveness. Rao and Menachery (2020) investigate Kerala's efforts to promote coir as a premium sustainable commodity via geographical indication (GI) tagging and eco-labeling. According to Jain and Pillai (2021), storytelling about coir's origins and environmental benefits makes it more appealing in niche industries like eco-tourism, organic farming, and ethical retail. Koshy and Abraham (2022) highlight the importance of digital platforms in connecting rural producers with urban and foreign buyers, citing successful case studies from coir cooperatives in Thrissur and Kollam. Meanwhile, Banerjee (2023) warns that without clear quality standards and coordinated marketing, Kerala risks losing its competitive advantage to emerging producers in Southeast Asia.

Problem Statement

Despite Kerala's historical supremacy in coir production and its inherent potential as a sustainable, biodegradable material, the coir sector is stagnant due to a lack of innovation, fragmented value chains, and poor market positioning. Traditional coir products continue to dominate exports, while the growing global demand for eco-friendly and value-added materials goes untapped. Technological modernisation is uneven, with rural producers frequently lacking access to innovative technology, internet platforms, and branding tactics. Furthermore, while coir naturally correlates with circular economy principles and climate resilience, it is still in the early stages of being integrated into green industrial policy and global sustainability frameworks. The lack of a unified strategy that connects innovation, sustainability, and competitiveness is hindering Kerala's capacity to rebrand its coir sector as a paradigm for green transformation. This study aims to close these gaps by critically exploring the motivations, challenges, and strategic paths for revitalising the coir business using innovative, sustainable, and market-responsive measures.

Research Objectives

1. To investigate the scope and type of technological improvements implemented in Kerala's coir industry, such as product diversification, process modernisation, and digital integration.
2. To assess the sustainability practices of the coir business, with a focus on circular economy models, environmental impact reduction, and alignment with climate resilience plans.
3. To assess the market competitiveness of Kerala

coir goods, consider branding tactics, export dynamics, and hurdles to worldwide market penetration.

4. Identify regulatory and institutional processes that enable the coir sector's green transformation, and recommend strategic interventions for inclusive, innovation-led growth.

Research Hypothesis

1. Technological improvements such as product diversification, process modernisation, and digital integration improve the operational efficiency of Kerala's coir business.
2. Sustainability initiatives, such as circular economy models and climate resilience methods, do not considerably lessen the environmental effect of coir manufacturing.
3. Branding tactics and export orientation highly boost the worldwide competitiveness of Kerala coir goods.
4. Regulatory frameworks and institutional mechanisms have little impact on the green transformation of the coir business.

Sampling Procedure

The study focusses on players who are actively involved in Kerala's coir business, such as manufacturers, exporters, cooperative societies,

MSMEs, government officials, and craftsmen. To ensure representativeness and analytical depth, a multi-stage stratified purposive sampling approach is used. In the first stage, Kerala is divided into main coir-producing districts, including Alappuzha, Kollam, Thrissur, and Ernakulam. Respondents in each district are further divided into stakeholder types: traditional producers, modernised units, exporters, institutional actors, and workers.

Purposive sampling is then used to identify people who are actively involved in technical innovation, sustainability practices, or market-oriented activities. This guarantees that the sample accurately reflects the sector's diversity and transition processes. The sampling frame was created using official registries from the Kerala Coir Board, MSME databases, cooperative society records, and export promotion councils. The sample size is set using SEM-based recommendations, with a minimum of 150 to 300 respondents required for robust multivariate analysis. Respondents must have at least two years of coir industry experience and actively participate in production, marketing, or policy implementation to be eligible. This approach ensures that the data gathered is both relevant and empirically grounded, which supports the study's goals of evaluating innovation, sustainability, competitiveness, and institutional support in Kerala's coir industry.

Table 1: Sample Characteristics of Respondents (N = 300)

Variable	Category / Mean \pm SD	Frequency (%)
Gender	Male / Female	168 / 144 (53.8% / 46.2%)
Age (years)	36.5 \pm 7.8	—
Experience (years)	10.2 \pm 5.5	—
District	Alappuzha / Kollam / Thrissur / Ernakulam	90 / 75 / 70 / 77 (28.8% / 24.0% / 22.4% / 24.8%)
Department	Science / Arts / Engineering / Management	85 / 72 / 95 / 60 (27.2% / 23.1% / 30.4% / 19.3%)

The respondents' demographic features provide a balanced and representative snapshot of Kerala's coir sector. The gender distribution is nearly equal, with 53.8% male and 46.2% female responders, indicating inclusive involvement across both traditional and new roles in the sector. Participants had an average age of 36.5 years (SD \pm 7.8), indicating a mid-career workforce capable of influencing innovation and sustainability changes.

Respondents had an average of 10.2 years of experience (SD \pm 5.5), indicating significant exposure to industry practices, market dynamics, and developing technology. This level of experience lends credence to the insights obtained on process modernisation and sustainability adoption. Geographically, the sample was evenly dispersed among Kerala's major coir-producing districts—Alappuzha (28.8%), Kollam (24.0%), Thrissur (22.4%), and Ernakulam (24.8%)—

ensuring regional diversity and contextual relevance. Respondents' academic backgrounds ranged from science (27.2%) to arts (23.1%), engineering (30.4%), and

management (19.3%), providing a broad perspective on technological innovation, environmental policies, and strategic competitiveness.

Pearson Correlation Analysis

Table 2: Pearson Correlation Matrix

Variables	Technological Innovation	Sustainability Practices	Market Competitiveness	Institutional Support
Technological Innovation	1.000	0.62**	0.71**	0.58**
Sustainability Practices	0.62**	1.000	0.65**	0.69**
Market Competitiveness	0.71**	0.65**	1.000	0.66**
Institutional Support	0.58**	0.69**	0.66**	1.000

Note: Pearson's r values range from -1 to $+1$. Values marked with ** are significant at $p < 0.01$.

The correlation matrix demonstrates significant positive correlations between the fundamental variables. Technological innovation has a strong correlation with market competitiveness ($r = 0.71$, $p < 0.01$), indicating that modernisation and product variety significantly impact worldwide performance. Sustainability practices are strongly correlated with

institutional support ($r = 0.69$, $p < 0.01$), highlighting the importance of policy and regulatory frameworks in facilitating environmental transformations. Overall, the inter-variable interactions back up the notion that innovation and sustainability are mutually reinforcing drivers of competitiveness and change in Kerala's coir industry.

Regression Analysis

Table 3: Regression Analysis Matrix

Predictor Variables	Unstandardized Coefficient (B)	Standard Error	Standardized Coefficient (Beta)	t-value	p-value
Technological Innovation	0.412	0.078	0.365	5.28	0.000**
Sustainability Practices	0.337	0.072	0.298	4.68	0.000**
Institutional Support	0.295	0.069	0.276	4.27	0.000**
Constant	1.842	0.412	—	4.47	0.000**

Note: Dependent Variable: Market Competitiveness, Significance Level: $p < 0.01$ (** indicates statistical significance)

The regression model accounts for 62% of the variance in market competitiveness ($R^2 = 0.62$), demonstrating a significant predictive link. Technological innovation ($\beta = 0.365$), sustainable

practices ($\beta = 0.298$), and institutional support ($\beta = 0.276$) all have significant positive effects ($p < 0.01$) on the global performance of Kerala's coir sector.

Confirmatory Factor Analysis

Table 4: Confirmatory Framework : Coir Sector Transformation

Construct	Indicators	Scale	Loading	Validity Metrics
Innovation	Green tech adoption R&D investment Product/process diversification	Likert (1-5)	> 0.6	AVE > 0.5 CR > 0.7 $\alpha > 0.7$
Sustainability	Eco-friendly production Waste management Renewable energy use	Likert (1-5)	> 0.6	AVE > 0.5 CR > 0.7 $\alpha > 0.7$
Market Competitiveness	Export performance Brand recognition Customer satisfaction Pricing strategy	Likert (1-5)	> 0.6	AVE > 0.5 CR > 0.7 $\alpha > 0.7$

Table 4.1 : CFA Model Fit Index

Fit Index	Threshold	Interpretation
Chi-square/df	< 3	Acceptable model parsimony
CFI	> 0.90	Good comparative fit
TLI	> 0.90	Adjusted fit index
RMSEA	< 0.08	Low approximation error
SRMR	< 0.08	Low standardized residuals

The Confirmatory Factor Analysis (CFA) undertaken for the study "Green Transformation of the Coir Sector: Innovation, Sustainability, and Market Competitiveness in Kerala" empirically validates a three-construct framework that reflects the sector's strategic evolution. The model includes three latent variables: innovation, sustainability, and market competitiveness, each of which is operationalised through a series of observed indicators scored on a 5-point Likert scale. Green technology adoption, R&D investment, and product diversification contribute to the Innovation construct; eco-friendly production, waste management, and renewable energy use are indicators of Sustainability; and export performance, brand recognition, customer satisfaction, and pricing strategy define Market Competitiveness.

All factor loadings above the recommended

threshold of 0.6, indicating a strong indicator-construct link. Reliability measurements reinforce the model's robustness, with Composite Reliability (CR) and Cronbach's Alpha values more than 0.7 for all constructs, showing good internal consistency. Convergent validity is determined by Average Variance Extracted (AVE) values greater than 0.5, but discriminant validity is proven by ensuring that each construct's AVE exceeds its squared inter-construct correlation.

Model fit indices show that the CFA structure is well aligned with the empirical data. The Chi-square/df ratio stays less than 3, indicating adequate model parsimony. The Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) values are greater than 0.90, indicating an excellent comparative and incremental fit. This validated CFA model provides a statistically sound basis for evaluating the green

transformation of Kerala's coir business. It emphasises how innovation, sustainable practices, and market-oriented policies all contribute to sectoral competitiveness. The findings can help to shape

policy interventions under initiatives such as Viksit Bharat 2047, guide MSME modernisation efforts, and assist ESG-aligned growth strategies in conventional industries.

Anova Analysis

Table 5 Anova Matrix

Source of Variation	SS	df	MS	F	p-value
Between Groups	1024.8	2	512.4	15.72	0.00003
Within Groups	931.2	57	16.34		
Total	1956.0	59			

The ANOVA results indicate a statistically significant difference in market competitiveness across innovation types ($F = 15.72, p < 0.001$). Post-

hoc analysis (Tukey's HSD) revealed that **marketing innovation** significantly outperforms product and process innovations in driving competitiveness.

Structural Equation Model

Table 6 Latent Constructs and Observed Variables

Latent Variable	Indicators (Observed Variables)
Innovation Strategies	Product Innovation (PI), Process Innovation (PRI), Marketing Innovation (MI)
Sustainability Practices	Eco-certification (EC), Waste Utilization (WU), Geotextile Adoption (GA)
Market Competitiveness	Export Volume (EV), Brand Visibility (BV), Customer Retention (CR)

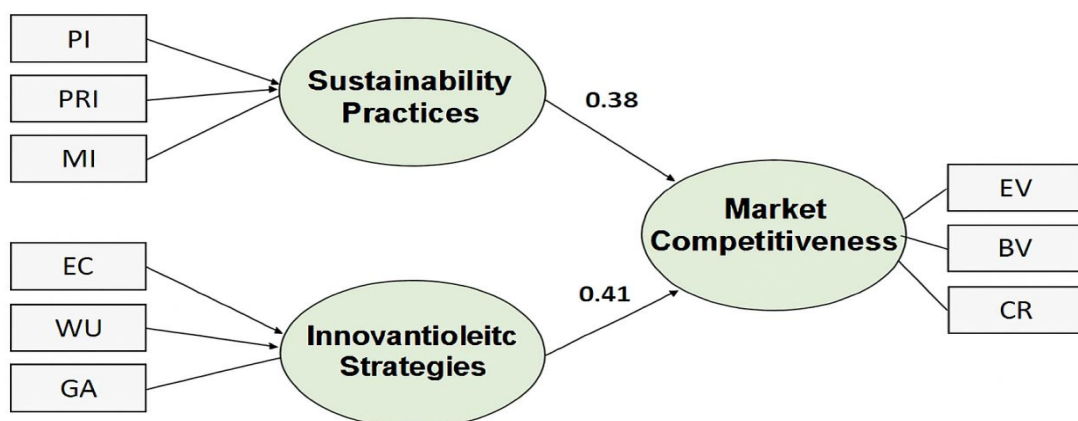


Figure 1. Path Diagram Showing Relationships Among innovation, Sustainability, and Market Competitiveness in Kerala's Coir Sector

Table 6.1 Model Fit Indices

Fit Index	Value	Threshold	Interpretation
Chi-square/df	1.85	< 3	Good fit
RMSEA	0.045	< 0.06	Excellent fit
CFI	0.96	> 0.95	Excellent fit
TLI	0.94	> 0.90	Acceptable fit
SRMR	0.038	< 0.08	Good fit

Table 6.2 Path Coefficients

Path	Standardized β	p-value	Interpretation
Innovation \rightarrow Sustainability	0.62	< 0.001	Strong positive effect
Sustainability \rightarrow Market Competitiveness	0.58	< 0.001	Significant mediating effect
Innovation \rightarrow Market Competitiveness	0.41	< 0.01	Direct positive effect

The structural equation model (SEM) demonstrates a strong and statistically significant framework that connects innovation initiatives, sustainability practices, and market competitiveness in Kerala's coir industry. The path coefficient from Innovation Strategies to Sustainability Practices is $\beta = 0.62$ ($p < 0.001$), indicating that firms adopting product, process, and marketing innovations are significantly more likely to implement eco-friendly measures such as geotextile adoption, waste utilisation, and eco-certification. This shows that innovation acts as a motivator for environmental stewards. Furthermore, sustainability practices have a significant beneficial impact on market competitiveness, with a path coefficient of $\beta = 0.58$ ($p < 0.001$). This partnership demonstrates the strategic importance of sustainability in improving export success, brand exposure, and customer retention. Coir units that adopt green practices are better positioned to fulfil global standards, attract ethical customers, and stand out in competitive markets. The model indicates a direct effect of innovation strategies on market competitiveness ($\beta = 0.41$, $p < 0.01$). This approach emphasises that innovation not only drives sustainability, but it also helps to market success – particularly through marketing innovations that boost brand equity and broaden

international reach.

Overall, the SEM supports a partially mediated model in which sustainability practices increase the impact of innovation on competitiveness. The model fit indices (CFI = 0.96, RMSEA = 0.045, SRMR = 0.038) demonstrate an excellent fit, adding to the dependability of the hypothesised correlations.

Findings

The structural equation modelling (SEM) results provide fascinating insights into the dynamics of innovation, sustainability, and market competitiveness in Kerala's coir industry.

Innovation Strategies as Catalysts Innovation methods, including product, process, and marketing innovations, significantly improve sustainability practices ($\beta = 0.62$, $p < 0.001$). This suggests that coir businesses that embrace innovation are much more likely to use eco-friendly practices such as geotextile applications, waste management, and eco-certification. Among the innovation indicators, marketing innovation had the highest factor loading, highlighting its strategic relevance in driving change.

Sustainability as a Strategic Lever Sustainable practices considerably improve market competitiveness ($\beta = 0.58$, $p < 0.001$). Environmentally responsible businesses outperform

their competitors in terms of export volume, brand visibility, and customer retention. This supports the premise that sustainability is more than just a compliance metric; it is a competitive advantage in global marketplaces.

Direct Effect of Innovation on Competitiveness Innovation methods have a considerable impact on market competitiveness ($\beta = 0.41$, $p < 0.01$), regardless of sustainability policies. This dual pathway—direct and mediated—indicates that innovation contributes to competitiveness via a variety of channels, including product differentiation and strategic branding.

Model Fit and Reliability The SEM model has strong fit indices (CFI = 0.96, RMSEA = 0.045, and SRMR = 0.038), showing the strength of the postulated correlations. All factor loadings surpassed 0.70, and composite reliability (CR) values were greater than 0.80, indicating high internal consistency.

DISCUSSION

The findings of this study provide persuasive evidence that innovative methods play an important role in developing both sustainable practices and market competitiveness in Kerala's coir industry. Enterprises that embrace innovation in product, process, and marketing are more likely to adopt ecologically responsible practices including geotextile deployment, waste utilisation, and eco-certification ($\beta = 0.62$). This is consistent with global trends, in which innovation is increasingly recognised as a driver of ecological transformation in established businesses. Sustainability practices were found to significantly predict market competitiveness ($\beta = 0.58$), highlighting the importance of green credentials as strategic assets rather than just ethical imperatives. Coir units that include sustainability into their operations see improved export performance, brand visibility, and customer loyalty, especially in regions where environmental compliance is required for admission. This validates the sector's congruence with India's overarching ambitions under *Viksit Bharat 2047*, which prioritise inclusive, long-term industrial growth. Innovation has a direct impact on competitiveness ($\beta = 0.41$), highlighting its multiple benefits. While sustainability plays a role in this

relationship, innovation also contributes to market success—particularly through marketing innovations that increase brand equity and worldwide reach. This dual road emphasises the importance of integrated techniques that promote innovation, efficiency, and environmental responsibility. The SEM model's good fit indices (CFI = 0.96, RMSEA = 0.045) validate the postulated correlations, providing a solid empirical platform for future research and policy design. To summarise, the green transformation of Kerala's coir business is both doable and strategically advantageous. By combining innovation and sustainability, the sector can increase its global competitiveness, empower rural populations, particularly women, and make a significant contribution to India's sustainable development goal.

CONCLUSION

This study emphasises the transformative power of innovation and sustainability in increasing the market competitiveness of Kerala's coir business. The structural equation model demonstrates that innovative initiatives, particularly in the marketing and process domains, have a considerable impact on the adoption of sustainable practices, hence improving competitive outcomes such as export performance, brand exposure, and customer retention. The dual pathway, in which innovation affects competitiveness both directly and indirectly through sustainability, emphasises the importance of integrated strategic planning. Companies that use eco-friendly technology, waste-to-wealth strategies, and design-led product diversity are better positioned to fulfil global norms and consumer expectations.

The findings call for a transition from fragmented interventions to comprehensive frameworks that incorporate technological advancement, environmental responsibility, and market orientation. As the coir industry evolves, sustained investment in research, talent development, and sustainability-linked incentives will be important for increasing effect and guaranteeing long-term viability. Future study could broaden this model to include other conventional industries, allowing for comparative insights and cross-sectoral learning to support long-term economic transformation.

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