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Green Manufacturing Practices And Products Quality Of Beverage Industry In Southwest, Nigeria

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Abstract
This study focused on green manufacturing practices and product quality in the beverage industry in Southwest Nigeria. The specific objectives of the study were to assess the extent to which green purchasing influences product reliability; examine the extent to which green technology affects product performance; and determine the extent to which green recycling affects product durability. The study employed a survey research design, targeting manufacturing firms located in Ogun, Lagos, Osun, Oyo, Ondo, and Ekiti States. The study employed both descriptive and inferential statistics for data analysis, using simple linear regression to test the formulated hypotheses. Findings revealed that green purchasing has significant positive influence on product reliability (given β= 0.794739; p-value <0.01); green technology has significant positive effect on product performance (given β= 0.789656; p-value <0.01); and green recycling has significant positive effect on product durability (given β= 0.769447; p-value <0.01). The study strongly supports the notion that green manufacturing practices play a crucial role in improving product quality within the beverage industry in Southwest Nigeria. The study recommended that firms should establish criteria for selecting suppliers based on their green purchase practices to ensure the reliability of their products, and that firms should invest in the research and development of innovative green technologies that enhance product performance while minimizing environmental impact.
Keywords: *Green Purchasing, Product Reliability, Green Technology, Product Performance, Green Recycling, Product Durability*

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I. Introduction

Globally, the concern for sustainability in manufacturing has deep historical roots, dating back to the Industrial Revolution in the 18th century. The rapid expansion of industrialization led to severe environmental consequences, including pollution, deforestation, and resource depletion. The modern sustainability movement gained momentum in the 1960s with Rachel Carson's book, *Silent Spring*, which raised awareness about pollution and environmental degradation. This ignited a global effort to address environmental challenges, including the emergence of green manufacturing practices (Bhatt et al., 2020; Gandhi et al., 2018; Machado, Winroth, & Ribeiro da Silva, 2020). Green manufacturing, as a formalized concept, took shape in Germany during the late 1980s and early 1990s and became widely recognized with the introduction of ISO 14001 in 1996, which set global standards for environmentally responsible production (Beaman et al., 2020; Karuppiah et al., 2020). This standard encouraged manufacturers worldwide to adopt waste reduction strategies, optimize raw material usage, and minimize environmental and health risks (Okunuga et al., 2022).

Manufacturing industries play a critical role in economic development but are also significant contributors to environmental degradation. The United Nations Environment Programme (UNEP, 2011) reported that the sector accounts for 20% of global carbon dioxide emissions and 35% of total electricity consumption. Additionally, manufacturing activities contribute to approximately 10% of global water use, a figure projected to exceed 20% by 2030. Furthermore, industrial operations generate about 17% of global air pollution. Given these statistics, manufacturers are increasingly compelled to adopt green manufacturing principles aligned with the Sustainable Development Goals (SDGs), which emphasize environmental protection, economic growth, and social equity (Khoshnava et al., 2019; Ye et al., 2023).

In Africa, the drive toward green manufacturing is growing as countries seek to align industrial processes with sustainable practices. Although the continent's manufacturing sector has developed at a slower pace compared to other regions, countries such as Nigeria, Morocco, and Egypt are making strides in adopting eco-friendly industrial practices (Gu et al., 2018; Tiba & Belaid, 2021; Wachira & Mathuva, 2022). Nigeria, in particular, has witnessed increased awareness and implementation of green manufacturing due to regulatory requirements, environmental ethics, and economic incentives. Nigerian industries are leveraging sustainable practices to minimize waste, optimize energy use, and comply with environmental regulations (Abanyam & Uwameiye, 2019; Madu, 2022; Mbang et al., 2020). The National Environmental Standards and Regulations Enforcement Agency (NESREA) Act of 2007, alongside the National Environmental (Food, Beverages, and Tobacco Sector) Regulations of 2009, provides regulatory frameworks to curb industrial pollution and promote sustainable manufacturing.

Despite these efforts, research on green manufacturing in Nigeria has largely focused on general sustainability and supply chain management, with limited empirical studies linking specific green manufacturing practices to product quality (Okunuga et al., 2022; Solaja & Adetola, 2020; Solaja, Adetola, & Okafor, 2020). Green manufacturing is widely recognized for its potential to enhance product attributes, including durability, reliability, and performance. For instance, green purchasing has been found to ensure the procurement of high-quality raw materials, thereby reducing defects and enhancing product reliability (Ghosh, 2019; Yook et al., 2017). Similarly, the adoption of green technology contributes to improved product performance by integrating innovative, energy-efficient production techniques (Nehra et al., 2023; Miranda et al., 2021). Furthermore, green recycling extends product lifespans and enhances durability by reducing waste and reusing materials efficiently (Alzlzly, 2023; Sandin & Peters, 2018).

While studies in other regions have explored the relationship between green manufacturing and product quality, there remains a research gap in understanding how these practices influence product reliability, performance, and durability in Nigeria's beverage manufacturing sector. Addressing this gap will provide insights into the benefits of sustainable production methods, informing policy and industry strategies for improving product quality through green manufacturing practices.

Objectives of the Study

The main objective of this study was to investigate the effect of green manufacturing on product quality in selected manufacturing companies in the beverage industry, Southwest -Nigeria. The specific objectives were to:

i. Assess the extent to which green purchasing influences product reliability.
ii. Examine the extent to which green technology affects product performance.
iii. Determine the extent to which green recycling affects product durability.

Research Questions

The study asked the following questions that:

i. In what ways could green purchasing affect product reliability?
ii. How does green technology affect product performance?
iii. What could be the potential effect of green recycling on product durability?

Research Hypotheses

The following hypotheses were formulated to guide the study:

i. Green purchasing has a significant effect on product reliability.
ii. Green technology has a significant effect on product performance.
iii. Green recycling has a significant effect on product durability.

II. Literature Review

This study investigates two primary variables: green manufacturing and product quality. Existing literature offers varied conceptualizations of these terms. The study aims to analyze these variables comprehensively and pinpoint specific indicators that illustrate the relationship between green manufacturing practices and product quality. By identifying these indicators, the research intends to enhance the understanding of how sustainable manufacturing processes can elevate product standards, ultimately providing a clearer framework for assessing the connection between green manufacturing and product quality.

Green manufacturing has emerged as a pivotal trend amid rising environmental awareness. This approach employs innovative strategies to optimize resource efficiency, minimize waste, and reduce industrial environmental impact. Companies adopting green manufacturing practices not only contribute to environmental protection but also gain a competitive edge in a sustainability-focused market. Fundamentally, it represents the "greening" of production processes, aiming to reduce ecological footprints while maximizing resource efficiency (Bui et al., 2024). Green manufacturing encompasses a holistic approach that integrates sustainability across all production stages, driving economic efficiency by minimizing pollution and waste (Elemure et al., 2023). By implementing techniques like reverse supply chain management and life cycle assessment, organizations can effectively manage environmental impacts and embed sustainability into core operations (Haleem et al., 2023). This transition is crucial for addressing pollution and waste management challenges, positioning companies favorably in an eco-conscious marketplace (Luan et al., 2022).

Product quality refers to the degree to which a product consistently meets established standards, specifications, and customer expectations. It encompasses attributes such as precision, reliability, and adherence to design processes, ensuring products are defect-free and function as intended (Bhaskar, 2022; Javaid et al., 2021). A high-quality product satisfies predefined criteria, emphasizing that meeting customer expectations is fundamental to quality, often more than mere excellence. Organizations can enhance reliability and customer satisfaction by employing efficient quality management techniques, such as rigorous testing and process control. Ultimately, compliance with these standards fosters customer trust and loyalty, positioning product quality as a critical factor in achieving long-term success.

In manufacturing, product quality encompasses various attributes, including serviceability, perceived quality, reliability, performance, and durability (Bekele, 2020; Syafarudin, 2021). Serviceability refers to ease of maintenance, while perceived quality reflects consumers' overall impressions based on brand reputation. Reliability indicates consistent performance over time, and durability reflects the product's lifespan under normal usage. High product quality ensures customer satisfaction, leading to repeat business and brand loyalty. Manufacturers can reduce returns and warranty claims by delivering reliable, high-performing products, ultimately enhancing their market position. Implementing rigorous quality control processes and adhering to international standards, such as ISO 9001, allows manufacturers to consistently meet or exceed customer expectations, reinforcing their commitment to quality and fostering long-term business success.

Green Purchasing and Product Reliability

Green purchasing refers to the procurement of products and services that minimize environmental impact throughout their lifecycle. As awareness of environmental issues grows among organizations and consumers, this practice has gained significant attention (Shao & Ünal, 2019). Product reliability—the likelihood a product will perform as intended without issues—plays a critical role in satisfying customer needs and enhancing brand loyalty, while also reducing repair costs and bolstering business reputation. Green purchasing can significantly influence product reliability, primarily through improved quality control (Khan et al., 2023). Organizations that adopt green purchasing often prioritize quality in supplier selection (Govindan et al., 2018). Sustainable suppliers typically invest in superior materials and production methods, enhancing product robustness. Companies engaged in green purchasing often form long-term partnerships with like-minded suppliers, further ensuring product reliability (Kumar et al., 2021). This approach encourages a lifecycle perspective, assessing environmental impacts at each stage of a product's life, from raw material extraction to disposal (De Giacomo et al., 2019). By focusing on lifecycle considerations, organizations can identify potential reliability issues early. Furthermore, green purchasing fosters innovation in product design, leading to improved durability and performance. Studies indicate that companies embracing sustainable practices often experience lower product failure rates and enhanced reliability (Abu-Seman et al., 2019; Al-Adamat et al., 2020). Thus, the long-term effects of green purchasing on product reliability merit further exploration.

Green Technology and Product Performance

Green technology has significant potential to enhance product performance, often leading to the creation of more energy-efficient products (Guo et al., 2020; Singh et al., 2022). For instance, appliances designed with advanced energy-efficient technology minimize energy consumption while maintaining functionality. This not only satisfies consumer demand for sustainability but also reduces operational costs throughout the product's lifecycle. Moreover, green technology frequently incorporates sustainable materials, resulting in improved durability and overall performance (Ikram et al., 2021). Products made from recycled materials, for example, can offer superior physical properties compared to traditional ones, making them lighter, stronger, and more resistant to wear (Cenci et al., 2022; Sfameni et al., 2023). Additionally, green technology enhances user experience by promoting features that foster engagement and satisfaction (Font et al., 2021). Smart home devices that optimize energy use provide real-time feedback, enriching user interaction.

Manufacturers are encouraged to invest in green technology due to rising consumer and regulatory demands for sustainable practices (Acquah et al., 2021; Shahzad et al., 2022). Although initial costs may be high, long-term savings in energy and materials can be substantial, and companies may qualify for governmental incentives (Yi et al., 2022; Song et al., 2023). Studies consistently show that adopting green practices correlates with improved product outcomes, customer satisfaction, and market share (Gelderman et al., 2021; Tu & Wu, 2021). Furthermore, research indicates that implementing green technology enhances operational performance, reinforcing the notion that sustainable practices can boost overall business performance and product quality (Elrayah & Ooi, 2023).

Green Recycling and Product Durability

Green recycling has emerged as a crucial strategy for enhancing product longevity amid global challenges in waste management and environmental degradation. Defined by Savciuc and Gangan (2023), green recycling involves the collection, analysis, and repurposing of materials to minimize environmental impacts, conserve resources, and promote sustainability. By improving product durability, green recycling reduces waste and extends product lifespans. Understanding its role in enhancing durability is vital for a sustainable future. This approach often leads to the creation of long-lasting products, as it encourages the use of high-quality recycled materials that can match or exceed the performance of virgin materials (Alassali et al., 2021; Roosen et al., 2023). For instance, recycled paper, plastic, and metal can be treated to restore their original strength, making them suitable for durable applications while decreasing the demand for new raw materials. Additionally, green recycling fosters innovation in material science (Le et al., 2022). As industries increasingly utilize recycled materials, advancements in polymer mixing and composites result in more resilient recycled plastics, enhancing product performance and lifecycle.

Empirical studies demonstrate a positive link between green recycling and product durability. For example, Salehi et al. (2021) found that products made from recycled materials often match or surpass those made from virgin materials in durability. Furthermore, Hartini et al. (2021) showed that integrating recycling with lean manufacturing increases product quality and longevity. Recycling not only conserves resources but enhances product durability, leading to more resilient and long-lasting goods.

III. Methodology

Research Design

The study employed a survey research design that utilized a standardized research instrument to systematically gather information and collect data. This design allowed for the exploration of cause-and-effect based on the data collected and analyzed.

Area of the Study

The study examined the effect of green manufacturing on product quality within selected manufacturing companies in the beverage industry in Southwest Nigeria. Specifically, it focused on companies located in Ogun, Lagos, Osun, Oyo, Ondo, and Ekiti States, which are recognized for their diverse industrial activities and dynamic business environments.

Population and Sample Size of the Study

The population of this study was potential respondents of manufacturing companies. The focal point of interest in this research comprises key employees of the manufacturing companies. For this study, a purposive sample size of 350 was selected.

Description of Research Instruments

The research instrument for the study was questionnaire. The scale for measuring green manufacturing in this study was created by conducting a thorough review of existing literature, aiming to establish a framework specifically tailored for assessing variables within green manufacturing. The study established measures of green manufacturing like green purchasing, green technology and green recycling. The proxy of product quality are product reliability, product performance and product durability. The instrument is designed using a five-point Likert scale ranging from strongly agree (5), agree (4), undecided (3), disagree (2) and strongly disagree (1).

Validity of the Research Instrument

The study used construct validity. Detailed results of the factor loadings for each construct are presented in Table 1 for thorough analysis and interpretation.

Table 1 Validation of Instrument

Indicator Variable	Loading	Square of Loading	Sum of the square loading	AVE	CR
Green Purchasing					
GRP1	0.8	0.64	2.936903	0.5873806	0.766407594
GRP2	0.721	0.519841			
GRP3	0.817	0.667489			
GRP4	0.767	0.588289			
GRP5	0.722	0.521284			
Green Technology					
GTI1	0.735	0.540225	2.92431	0.584862	0.764762708
GTI2	0.713	0.508369			
GTI3	0.834	0.695556			
GTI4	0.752	0.565504			
GTI5	0.784	0.614656			
Green Recycling					

GRR1	0.746	0.556516	2.974686	0.5949372	0.771321723
GRR2	0.772	0.595984			
GRR3	0.756	0.571536			
GRR4	0.755	0.570025			
GRR5	0.825	0.680625			
Product Reliability					
PRR1	0.748	0.559504	2.94778	0.589556	0.767825501
PRR2	0.823	0.677329			
PRR3	0.741	0.549081			
PRR4	0.779	0.606841			
PRR5	0.745	0.555025			
Product Performance					
PRP1	0.768	0.589824	3.115794	0.6231588	0.789404079
PRP2	0.722	0.521284			
PRP3	0.873	0.762129			
PRP4	0.754	0.568516			
PRP5	0.821	0.674041			
Product Durability					
PRD1	0.766	0.586756	3.023971	0.6047942	0.777685155
PRD2	0.778	0.605284			
PRD3	0.725	0.525625			
PRD4	0.791	0.625681			
PRD5	0.825	0.680625			

Source: AMOS SPSS, 2024

Data Analyses Techniques

The study used both descriptive and inferential statistics for data analysis. The data were presented in tables utilizing the percentage method to give a clear and concise overview of the respondents' demographics. Descriptive statistics, including the mean and standard deviation, were employed to analyze the survey responses, providing information into the central tendency and variability of the data. Furthermore, least squares regression were applied to test the formulated hypotheses. The models according to the objectives are specified thus:

$PQ = \beta0 + \beta_1 GM + \varepsilon$………………………………………………………..……… 1

$PRR = \beta_0 + \beta_1 GRP + \varepsilon$ …………………………………………………..…. 2

$PRP = \beta_0 + \beta_1 GTI + \varepsilon$ ……………………………………………………..… 3

$PRD = \beta_0 + \beta_1 GRR + \varepsilon$ ……………………………………………………….… 4

Where;
GRP = Green purchasing
GTI = Green technology
GRR = Green recycling
PRR = Product reliability
PRP = Product performance
PRD = Product durability

IV. Data Analyses And Results

Table 2 Gender of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Male	196	56.0	56.0	56.0
	Female	154	44.0	44.0	100
	Total	**350**	**100.0**	**100.0**	

Source: Field survey, 2024

Table 2 shows the gender of respondents. It shows that 196 respondents (56%) were male; 154 respondents (44%) were female. The implication is that majority of the respondents in the study area were male.

Table 3 Age of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Under 25	64	18.3	18.3	18.3
	25-34 Years	136	38.9	38.9	57.1
	35-44 Years	86	24.6	24.6	81.7
	45-54 Years	31	8.9	8.9	90.6
	55-64 Years	18	5.1	5.1	95.7
	65 and above	15	4.3	4.3	100.0
	Total	**350**	**100.0**	**100.0**	

Source: Field Survey, 2024

Table 3 presents the age distribution of respondents. It shows that 64 respondents (18.3%) were under 25 years; 136 respondents (38.9%) were within 25-34 years; 86 respondents (24.6%) were within 35-44 years; 31 respondents (8.9%) were within 45-54 years; 18 respondents (5.1%) were within 55-64 years; and 15 respondents (4.3%) were 65 years and above. The majority of the respondents in the study areas were within 25-34 years.

Table 4 Educational Background of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	SSCE	18	5.1	5.1	5.1
	OND/NCE	81	23.1	23.1	28.3
	HND/Bachelor's Degree	126	36.0	36.0	64.3
	Master's Degree	96	27.4	27.4	91.7
	Doctorate	22	6.3	6.3	98.0
	Other	7	2.0	2.0	100.0
	Total	**350**	**100.0**	**100.0**	

Source: Field survey, 2024

Table 4 shows the educational background of respondents. It indicates that 18 respondents (5.1%) has secondary school certificate; 81 respondents (23.1%) have ordinary national diploma certificate; 126 respondents (36.0%) hold higher national diploma certificate/Bachelor's degree; 96 respondents (27.4%) hold a master's degree; 22 respondents (6.3%) hold a doctorate degree; and 7 respondents (2.0%) hold other certificates. The results show that a substantial proportion of respondents have a sufficient level of educational background relevant to understanding the subject matter.

Table 5 Years of experience of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Less than 1 year	66	18.9	18.9	18.9
	1-3 years	79	22.6	22.6	41.4
	4-6 years	93	26.6	26.6	68.0
	7-10 years	74	21.1	21.1	89.1
	More than 10 years	38	10.9	10.9	100.0
	Total	**350**	**100.0**	**100.0**	

Source: Field Survey, 2024

Table 5 shows the years of experience of the respondents. It indicates that 66 respondents (18.9%) had less than 1 year of experience; 79 respondents (22.6%) had 1-3 years of experience; 93 respondents (26.6%) had 4-6 years of experience; 74 respondents (21.1%) had 7-10 years of experience; and 38 respondents (10.9%) had more than 10 years of experience. The results reveal that the majority of respondents (69.2%) have between 1 and 10 years of experience, with 4-6 years being the most represented category at 26.6%. This means that most respondents possess a moderate to significant level of industry experience. However, the distribution reflects a diverse range of experience levels, enhancing the comprehensiveness of the study.

Table 6 Regression on Green Purchasing and Product Reliability

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.699827	0.114511	6.111429	0.0000
GRP	0.794739	0.033659	23.61150	0.0000
R-squared	0.615683	Mean dependent var		3.177143
Adjusted R-squared	0.614579	S.D. dependent var		1.382470
S.E. of regression	0.858269	Akaike info criterion		2.537900
Sum squared resid	256.3459	Schwarz criterion		2.559945
Log likelihood	-442.1325	Hannan-Quinn criter.		2.546675
F-statistic	557.5030	Durbin-Watson stat		1.942336
Prob(F-statistic)	0.000000			

Source: *Author's Computation Using E-views*

Model Line: $PRR = \beta_0 + \beta_1 GRP + \varepsilon$

Regression Line: $PRR = 0.699827 + 0.794739GRP$

Where; *PRR* = Product reliability, *GRP* = Green purchasing and ε = Stochastic error term.

Interpretation

Table 6 examines the effect of green purchasing (GRP) on product reliability. The R-squared value is 0.615683, indicating that approximately 61.6% of the variation in product reliability can be explained by green purchasing. This suggests a moderate to strong relationship between the two variables, with the remaining 38.4% of the variation attributed to other factors not included in the model. The adjusted R-squared value of 0.614579, which is very close to the R-squared, indicates that the model is well-fitted, with minimal inflation due to additional variables. The standard error of the regression is 0.858269, representing the average distance that observed values fall from the regression line. A lower standard error indicates a better fit of the model. The sum squared residuals is 256.3459, measuring the total deviation of response values from the predicted values, further contributing to the understanding of the model's accuracy. Model selection criteria show the Akaike Information Criterion (AIC) at 2.537900, the Schwarz Criterion at 2.559945, and the Hannan-Quinn Criterion at 2.546675. These criteria assist in comparing models, with lower values indicating a better fit. The F-statistic for the model is 557.5030, with an associated p-value of 0.000000, confirming that the overall model is statistically significant. This implies that green purchasing as an independent variable significantly explains the variability in product reliability. The Durbin-Watson statistic is 1.942336, which is reasonably close to 2, indicating that there is no significant autocorrelation present in the residuals, implying that the assumptions of the regression are not violated.

The coefficient for the constant term (C) is 0.699827, with a standard error of 0.114511, which means the intercept of the regression line is statistically significant. The high t-statistic of 6.111429 and a p-value of 0.0000 suggest that the constant term is significantly different from zero, implying a baseline level of product reliability (0.70) when green purchasing is absent. The coefficient for green purchasing (GRP) is 0.794739, with a standard error of 0.033659. This indicates a strong positive relationship between green purchasing and product reliability. The large t-statistic of 23.61150 and the p-value of 0.0000 confirm that this relationship is statistically significant. In practical terms, for every unit increase in green purchasing, product reliability is expected to increase by approximately 0.79 units, assuming other variables remain constant. This highlights that green purchasing is an important factor influencing and improving product reliability.

From the above analysis, it is clearly seen that the p-value is less than 0.01. So, we reject the null hypothesis (Ho) and then conclude that green purchasing has significant positive influence on product reliability.

Table 7 Regression on Green Technology and Product Performance

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.707859	0.105937	6.681873	0.0000
GTI	0.789656	0.031606	24.98400	0.0000
R-squared	0.642049	Mean dependent var		3.140000
Adjusted R-squared	0.641021	S.D. dependent var		1.304763
S.E. of regression	0.781747	Akaike info criterion		2.351128
Sum squared resid	212.6729	Schwarz criterion		2.373173
Log likelihood	-409.4474	Hannan-Quinn criter.		2.359903
F-statistic	624.2004	Durbin-Watson stat		1.856355
Prob(F-statistic)	0.000000			

Source: *Author's Computation Using E-views*

Model Line: $PRP = \beta_0 + \beta_1 GTI + \varepsilon$

Regression Line: $PRP = 0.707859 + 0.789656GTI$

Where; *PRP* = Product performance, *GTI* = Green technology and ε = Stochastic error term.

Interpretation

Table 7 examines the effect of green technology (GTI) on product performance. The R-squared value is 0.642049, indicating that approximately 64.2% of the variation in product performance can be explained by green technology. This suggests a moderate to strong relationship between the two variables, with the remaining 35.8% of the variation attributed to other factors not included in the model. The adjusted R-squared value of 0.641021, which is very close to the R-squared, indicates that the model is well-fitted, with minimal inflation due to additional variables. The standard error of the regression is 0.781747, representing the average distance that observed values fall from the regression line. A lower standard error suggests a better fit of the model. The sum squared residuals is 212.6729, which measures the total deviation of response values from the predicted values, further assisting in assessing the model's accuracy. Model selection criteria show the Akaike Information Criterion (AIC) at 2.351128, the Schwarz Criterion at 2.373173, and the Hannan-Quinn Criterion at 2.359903. These criteria help compare models, with lower values indicating a better fit. The F-statistic for the model is 624.2004, with a p-value of 0.000000, confirming that the overall model is statistically significant. This implies that green technology significantly explains the variability in product performance. The Durbin-Watson statistic is 1.856355, which is close to 2, suggesting no significant autocorrelation in the residuals, implying that the assumptions of the regression are not violated.

The coefficient for the constant term (C) is 0.707859, with a standard error of 0.105937. The high t-statistic of 6.681873 and p-value of 0.0000 indicate that the constant term is statistically significant. The coefficient for green technology is 0.789656, with a standard error of 0.031606. This coefficient's t-statistic of 24.98400 and p-value of 0.0000 demonstrate a strong and statistically significant positive relationship. For every unit increase in green technology, product performance increases by approximately 0.79 units, holding other factors constant. This result highlights the importance of green technology in enhancing product performance.

From the above analysis, it is clearly seen that the p-value is less than 0.01. So, we reject the null hypothesis (Ho) and then conclude that green technology has significant positive effect on product performance.

Table 8 Regression on Green recycling and Product durability

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.846216	0.110244	7.675861	0.0000
GRR	0.769447	0.035990	21.37922	0.0000
R-squared	0.567740	Mean dependent var		2.974286
Adjusted R-squared	0.566498	S.D. dependent var		1.346510
S.E. of regression	0.886554	Akaike info criterion		2.602749
Sum squared resid	273.5205	Schwarz criterion		2.624794
Log likelihood	-453.4811	Hannan-Quinn criter.		2.611524
F-statistic	457.0711	Durbin-Watson stat		1.595571
Prob(F-statistic)	0.000000			

Source: *Author's Computation Using E-views*

Model Line: $PRD = \beta_0 + \beta_1 GRR + \varepsilon$

Regression Line: $PRD = 0.846216 + 0.769447GRR$

Where; *PRD* = Product durability, *GRR* = Green recycling and ε = Stochastic error term.

Interpretation

Table 8 examines the effect of green recycling (GRR) on product durability. The R-squared value is 0.567740, indicating that approximately 56.8% of the variation in product durability can be explained by green recycling. This suggests a moderate relationship between the two variables, with the remaining 43.2% of the variation attributed to other factors not included in the model. The adjusted R-squared value of 0.566498, which is very close to the R-squared, indicates that the model is well-fitted with minimal inflation due to additional variables. The standard error of the regression is 0.886554, representing the average distance that observed values fall from the regression line, with lower values indicating a better model fit. The sum squared residuals is 273.5205, measuring the total deviation of response values from the predicted values, contributing to an understanding of the model's accuracy.

Model selection criteria show the Akaike Information Criterion (AIC) at 2.602749, the Schwarz Criterion at 2.624794, and the Hannan-Quinn Criterion at 2.611524. These criteria help in comparing models, with lower values indicating a better fit. The F-statistic for the model is 457.0711, with a p-value of 0.000000, confirming that the overall model is statistically significant. This implies that green recycling significantly explains the variability in product durability. The Durbin-Watson statistic is 1.595571, which is somewhat below 2, indicating the presence of some positive autocorrelation in the residuals. However, this does not necessarily violate the regression assumptions.

The coefficient for the constant term (C) is 0.846216, with a standard error of 0.110244. The high t-statistic of 7.675861 and p-value of 0.0000 indicate that the constant term is statistically significant. The coefficient for green recycling (GRR) is 0.769447, with a standard error of 0.035990. The large t-statistic of 21.37922 and the p-value of 0.0000 demonstrate a strong and statistically significant positive relationship. In practical terms, for every unit increase in green recycling, product durability is expected to increase by approximately 0.77 units, assuming other factors remain constant. This result highlights the significant role of green recycling in enhancing product durability.

From the above analysis, it is clearly seen that the p-value is less than 0.01. So, we reject the null hypothesis (Ho) and then conclude that green recycling has significant positive effect on product durability.

V. Discussion Of Findings

The study assessed the extent to which green purchasing influences product reliability. Finding showed that green purchasing has significant positive influence on product reliability. This implies that when firms prioritize green purchasing—sourcing materials and components that are environmentally sustainable and of high quality—they can positively affect the durability and dependability of their products. This study aligns with previous research that has established the positive relationship between sustainable supply chain practices and product performance. For example, Famiyeh et al. (2018) found that green sourcing strategies contribute to enhanced product reliability by ensuring consistency in material properties and reducing the occurrence of defects. However, this study advances prior research by focusing specifically on the connection between green purchasing and product reliability, which has been less frequently examined in the literature. The finding also aligns with the finding of González-Viralta et al. (2023) that highlight the significance of eco-friendly practices in fostering customer satisfaction and influencing various consumer behaviors. Green purchasing reinforces quality by incorporating sustainability as a quality criterion. On the other hand, while most empirical studies, such as those by Ghosh (2019) and Song et al. (2017), highlight the environmental benefits of green procurement, this study contributes by showing that such practices also support traditional product performance metrics like reliability.

The study examined the extent to which green technology affects product performance. Finding unveiled that green technology has significant positive effect on product performance. This implies that companies that invest in green technology—such as the adoption of energy-efficient production methods, the use of renewable energy sources, or the development of eco-friendly product features—are likely to see enhanced product performance. Rezende et al. (2019) found that green technological innovation positively impacts both environmental and economic performance, with product performance being a key component. Similarly, studies by Wang and Bai (2019) and Chen and Liu (2020) showed that green technology enhances product quality and consumer perception, reinforcing the notion that sustainability-focused technology investments yield tangible product benefits. This study advances the understanding by specifically focusing on the direct effect of green technology on product performance, contributing an additional layer of evidence to the body of research in this area.

The study determine the extent to which green recycling affects product durability. Finding indicated that green recycling has significant positive effect on product durability. This finding implies that firms that incorporate green recycling—such as the reuse of materials, the implementation of circular production models, and the minimization of resource waste—are likely to produce more durable products that withstand longer usage and maintain quality over time. Dey et al. (2020) demonstrated that recycling practices contribute to enhanced material efficiency and sustainability in manufacturing, which can, in turn, improve the longevity of products. Additionally, studies by Abdul-Rashid et al. (2017) and Yildiz Çankaya, and Sezen (2019) pointed out that integrating circular economy principles, including recycling, supports durable product design and reduces reliance on virgin materials, reinforcing the environmental and performance advantages of such practices. This study adds value by establishing a direct link between green recycling and product durability, advancing the discourse around sustainable manufacturing.

VI. Conclusion

This study has yielded compelling evidence that green manufacturing practices enhance product quality. In a world increasingly focused on sustainability, the importance of adopting green practices cannot be overstated. The evidence presented underscores the undeniable link between environmentally friendly initiatives and improved product attributes, including reliability, performance, and durability. As consumers become more discerning and environmentally conscious, companies that prioritize green practices are likely to benefit from increased customer loyalty and market competitiveness. By committing to sustainable product development and operational processes, organizations can not only contribute to environmental stewardship but also ensure their products stand out in an ever-evolving marketplace.

VII. Recommendations

Based on the findings of the study, the following recommendations are made that:

i. Firms should establish criteria for selecting suppliers based on their green purchase practices to ensure the reliability of their products. Engaging in partnerships with certified green suppliers can enhance overall product quality and performance. Additionally, conducting regular assessments of supplier practices will help maintain high standards in product reliability and consumer confidence.

ii. Firms should invest in the research and development of innovative green technologies that enhance product performance while minimizing environmental impact. Collaborating with experts in sustainable technologies can lead to breakthrough innovations that set products apart in the marketplace.

iii. Firms should incorporate design strategies that facilitate recycling and promote the use of durable materials, thereby enhancing product durability. Implementing take-back programs can encourage consumers to return products for recycling, reducing waste and promoting a circular economy. Educating consumers about the benefits of recycling and the durability of products can strengthen brand loyalty and environmental awareness.

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