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Evaluating the Adoption and Socioeconomic Impacts of Technological Innovations in the Kola Nut Processing Industry

BY

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Abstract

The kola nut sector is now exploring technological improvements aimed at enhancing processing methods and is vital in various socio-economic circumstances. This study examined the perceptions and implementation of novel processing techniques, such as freeze drying, microwave drying, and supercritical carbon dioxide extraction. The current and potential application of these technologies was assessed by electronically gathering data from key industry stakeholders via a tailored Google form. The study revealed a traditional reliance on sun drying (38%), oven drying (22%), and a burgeoning utilization of microwave drying (10%). Stakeholders have highlighted the main issues with present processing methods as cost (22%), environmental impact (20%), and product quality (24%). A significant proportion of respondents (33.3%) exhibit a moderate understanding of innovative technology, whilst 25% display a high level of comprehension. Cost-effectiveness (25%), environmental advantages (19%), and improvements in product quality (18%) are key reasons influencing the adoption of new technology. Respondents indicate that the principal advantages of these technologies are improved product quality (28%) and heightened processing efficiency (30%). The principal barriers to the adoption of these innovations are the substantial initial expenses (31%) and a deficiency of technical competence (27%). Seventy-five percent of respondents indicate that other industry stakeholders should invest in innovative technologies. This study emphasized the need for initiatives to minimize costs and enhance technical training to promote the general use of sophisticated processing techniques in the kola nut business.

Keywords: *Kola nut processing, technological innovation, industry challenges, technology adoption.*

Introduction

Kola nuts, native to the tropical rainforests of East Africa, has significant cultural, social, and economic value in West Africa. The caffeine content of Cola nitida and Cola acuminata is highly valued, leading to its significant presence in traditional rituals, social conventions, religious ceremonies, and communal meetings (Falola & Heaton, 2008; Peil, 1995). Kola nuts represent peace and hospitality and are utilized in traditional African medicine to address ailments such as migraines, digestive disorders, and fatigue. Moreover, they are utilized in social contexts to foster ties and formalize transactions, as well as in religious and spiritual spheres (Adebowale & Adeyemi, 2004). The symbolic significance of kola nuts arises from its connection to various numbers and colors. They provide an economic function in local communities by producing income for producers and retailers. The nuts exhibit a deep and intricate amalgamation of cultural, social, religious, medical, and economic aspects. Their continued significance in West African civilizations is evidenced by their extensive array of cultural and spiritual traditions (Hart, 1982).

Kola nuts constitute a vital commercial product in West Africa, especially in nations such as Nigeria, Côte d'Ivoire, and Ghana. Small-scale farmers cultivate and trade them, generating revenue for communities and fulfilling fundamental needs such as food, education, and healthcare (Adedeji, 2007). Adebayo et al. (2012). The kola nut industry creates jobs in processing, packing, and trading, and contributes to the GDP of producing nations (Akinwale, 2010; Falola & Heaton, 2008). Kola nuts contribute to cultural

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tourism, promoting economic development and enhancing awareness of their cultural significance. They are in high demand globally in nations with substantial West African diasporas, facilitating commercial initiatives and preserving connections between West Africans and their ancestry outside. Kola nuts are utilized in the pharmaceutical industry and as a flavoring agent in food and beverage production. Adebowale and Adeyemi, 2004.

Kola nuts, a fundamental crop in West Africa, are conventionally processed using manual techniques such as harvesting, curing, and drying. These methods, grounded in cultural norms, exhibit constraints in efficiency and scalability. Technological innovations have revolutionized the business, improving operating efficiency and product quality (Odebunmi, 2008; Akusu, 2018; Oluwalana 2015) Mechanized harvesting apparatus, automated sorting systems, and enhanced drying techniques have augmented productivity and diminished labor expenses. Innovative methods such as sun dryers and improved fermentation procedures have refined curing, prolonging shelf life and elevating nut quality, while the paper presented a summary of the key technological advancements in kola nut processing (Kouassi, 2017; Adeniji, 2018).

Automated sorting and grading techniques for kola nuts have enhanced uniformity and quality, resulting in increased market value (Okafor & Adewumi, 2020). Efficient washing systems, including solar dryers and heat pump dryers, utilize reduced water and energy, integrating rotating brushes and eco-friendly cleaning ingredients (Johnson, 2019, Sangotayo et al.2017). Conventional sun drying techniques are being supplanted by solar dryers and heat pump dryers, which regulate temperature and humidity consistently, hence improving the quality and longevity of kola nuts (Emeka, 2021; Chukwu & Okonkwo, 2022). Advanced packaging techniques such as vacuum sealing and modified environment packing prolong the shelf life of kola nuts by inhibiting oxidation and deterring insect infestation. With the escalation of processing operations, effluent treatment technologies become imperative, utilizing wastewater treatment systems that integrate biofilters and wetlands to address organic loads (Adebayo & Hassan, 2020).

Technological innovations in kola nut processing have enhanced efficiency, elevated quality, and bolstered market competitiveness, culminating in more revenues for stakeholders. This has enhanced food security and livelihoods in kola nut-producing communities (Oladapo & Alabi, 2020; Adewale & Ojo, 2023). Technology transfer projects provide local farmers with advanced equipment and training programs. These innovations boost economic productivity and contribute to sustainability in the kola nut sector (Balogun & Ogunlowo, 2021). Mechanization diminishes environmental impacts and allows manufacturers to satisfy growing domestic and worldwide demand. Technological advancements have markedly revolutionized the processing of kola nuts, improving efficiency, quality, and market attractiveness. Mechanical harvesters and automated sorting systems have diminished labor expenses and processing times, enabling the processing of greater volumes of nuts in lower durations (Adeniji, 2018; Bankole, 2019). Innovative drying and packaging technologies have prolonged the shelf life of kola nuts, creating new market opportunities both domestically and internationally (Adebayo & Hassan, 2020; Eze, 2012). Effluent treatment technology has diminished the environmental impact of kola nut manufacturing by treating wastewater and preserving local ecosystems (Chukwu & Okonkwo, 2022; Okafor & Adewumi, 2020). Technological developments in kola nut processing have stimulated economic growth in producing regions, enhancing profits for farmers, processors, and exporters (Itabiyi et al. 2024 & Obi, 2001).

Advancements in kola nut processing encounter obstacles stemming from substantial investment expenses and restricted access to infrastructure and training for small-scale producers. Subsequent research should prioritize cost-efficient, sustainable solutions customized for local populations and promote knowledge sharing and capacity building (Oladimeji., 2022). Despite the cultural, social, and economic importance of kola nuts in West Africa, the industry encounters numerous challenges that require resolution for sustainability and growth. Prospective developments and possible future trajectories may impact the kola nut sector (Olugbenga & Adeniyi, 2023).

Climate change presents substantial risks to kola nut farming, as alterations in temperature and precipitation impact tree growth and nut yield (Emodi et al., 2020). Deforestation and habitat degradation exacerbate pressures on kola nut-producing regions. Insects and illnesses, such as the kola weevil, might hinder yields and quality. Traditional pest management may prove inadequate against emerging pests, requiring different control measures (Eze, 2019). Entering international markets poses difficulties for small-scale cultivators due to rigorous quality standards, trade regulations, and competition. Technological developments can improve the efficiency of kola nut processing; however, implementation may be hindered by costs, infrastructural limitations, and the technical expertise of smallholder farmers (Olukosi & Akinola, 2017).

Climate change can affect kola nut production by introducing stressors such as drought and elevated temperatures. Breeding initiatives aimed at enhancing drought tolerance and disease resistance can fortify kola nut trees (Opeke, 2016). Integrated Pest Management strategies, encompassing biocontrol agents and resistant cultivars, can sustainably manage pests and illnesses (Eze , 2019). Investigating value-added commodities such as extracts, beverages, and dietary supplements may generate novel market prospects. Diversification into unconventional markets and investment in training can enhance the industry's competitiveness (Adeniji, 2018). Cooperative initiatives involving academic institutions, governmental organizations, and industry participants can facilitate technology transfer and information dissemination (Olukosi & Akinola, 2017). This study investigated the perceptions and use of innovative processing techniques,

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including freeze drying, microwave drying, and supercritical carbon dioxide extraction.

MATERIALS AND METHODS

Methodology for Research

This study employed a mixed-methods approach to assess the acceptance and attitudes of key stakeholders in the kola nut sector regarding three emerging processing technologies: Freeze Drying, Microwave Drying, and Supercritical Carbon Dioxide (CO_2) extraction. The study sought to gather quantitative and qualitative data from industry professionals to evaluate the current utilization of technology and the potential for adopting new approaches.

Collection of Data

Data was gathered via an online questionnaire conducted through a customized Google Form. The survey was electronically distributed to several stakeholders in the kola nut industry, including producers, processors, and industry experts. The questionnaire was designed to collect demographic information and detailed perceptions of new technologies, challenges to their deployment, and in-depth insights into current processing procedures. The questionnaire included both closed-ended and open-ended questions, allowing respondents to offer structured responses and qualitative observations.

Statistical sampling

The study utilized a purposive sampling strategy to deliberately identify people with direct involvement in the kola nut business and knowledge in the processing procedures under examination. The sample included notable figures from many areas of the industry, covering participants in both traditional and modern processing methods. A total of 100 stakeholders engaged in the poll, thereby providing a representative sample of the industry's viewpoints.

Survey Design

The questionnaire was structured into several sections:

I. Current Processing Practices: Participants were asked about the methods they currently utilize, including sun drying, oven drying, or microwave drying.

II. Perceptions of New Technologies: The study examined attitudes regarding the quality, cost, and environmental implications of Freeze Drying, Microwave Drying, and Supercritical CO_2 extraction.

III. Barriers and Benefits: Respondents provided insightful insights on the challenges they face, including financial limitations and insufficient technical skills, alongside the perceived benefits such as increased productivity and superior product quality.

IV. Future Recommendations: participants were asked about their willingness to advocate for financial investments in advanced technologies to other sector participants.

Analysis of Data

The quantitative data analysis employed descriptive statistics, focusing on percentages and frequency distributions. This investigation sought to understand the adoption rates and the primary factors influencing decision-making throughout the sector. Responses were classified to identify patterns in technology adoption, challenges faced, and perceived benefits. The qualitative data derived from open-ended questions underwent thematic analysis to achieve a thorough knowledge of the barriers and motivations associated with the adoption of new technologies.

Data analysis

Charts are employed to illustrate the data. Analysis of variance was implemented in this investigation. ANOVA is a statistical analysis instrument that is integrated into the Statistical Analysis System (SAS). It is employed to investigate the differences between groups in a sample by implementing a series of associated estimation procedures.

Formulation of Hypotheses

Hypothesis 1

H0 asserts that the year of experience is not significantly influenced by the comprehension of the utilization of innovative technologies in the kola nut, while H1 asserts that the year of experience is significantly influenced by the comprehension of the utilization of innovative technologies in the kola nut.

Hypothesis 2

H0 is the assertion that the comprehension of innovative technologies does not significantly influence occupations, while H1 is the assertion that the comprehension of innovative technologies does significantly influence occupations.

The hypotheses were tested using the Analysis of Variance (ANOVA) at a confidence level of 95% to confirm the findings.

Analysis of Variance (ANOVA) test

One-way and two-way analyses of variance are the two subdivisions of analysis of variance (ANOVA). ANOVA is employed to ascertain whether statistically significant differences exist among the means of three or more independent groups, and it is advantageous when assessing a minimum of three variables. Nonetheless, it generates a reduced number of type I mistakes and is relevant to a diverse range of issues. ANOVA categorizes differences by comparing group means and entails allocating variation among several sources. Statistical Analysis Software (SAS) was employed to calculate statistical measures of variation to facilitate improved decision-making, including ANOVA, skewness, kurtosis, and coefficient of variation. Skewness evaluates the asymmetry of data distribution relative to the mean, influenced by the existence of extreme values, whether lower or higher.

Kurtosis refers to the vertical deviation of a data distribution near the mean and its associated relative standard deviation. This also indicates variances resulting from the flatter and denser tails on both sides. The coefficient of variation quantifies the percentage variance when comparing two

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attributes with disparate units, enhancing clarity. The standard deviation is frequently utilized as a measure of variability, assessing the extent of variation among people relative to their common mean. The deviations denote the distances between specific data points and the mean.

Results and Discussions

Table 1 illustrates the socio-economic data of the respondents. It illustrates the distribution of respondents according to their employment status, profession, years of experience, and gender. The findings indicate that the majority of respondents, 50% (n = 36), had less than 5 years of experience, followed by 29% (n = 21) with 5-10 years of experience, 9% (n = 12) with 11-20 years of experience, and 8% (n = 6) with over 20 years of experience. Seventy-two respondents participated in the surveys; the data indicates that the predominant demographic was male (95.83%, n = 69), whilst female respondents constituted a minority (4.17%, n = 3). Government personnel are the largest segment at 58.33%, followed by private sector employees at 20.83% and students at 20.83%. The researcher constitutes the majority at 41.67%, followed by the farmer at 9% and the industrial consultant at 4%. Table 2 displays the descriptive statistics about the job status, occupation, year of experience, and sex distributions of the respondents.

Table 1: Job status, occupation, year of experience, and sex distributions of the respondents

Sex	Frequency	Percent
Female	3	4.17
Male	69	95.83
Total	72	100

Year of experience	Frequency	Percent
Less than 5 years	36	50.00
5-10 years	21	29.17
11-20 years	9	12.50
More than 20 years	6	8.33
Total	72	100

Occupation	Frequency	Percent
Government Employee	42	58.33
Personal Employee	15	20.83
Students	15	20.83
Total	72	100

Job Status	Frequency	Percent
Industry consultant	3	4.17
Farmer/Producer	6	8.33
Researcher/Academic	30	41.67
Processor;Others	3	4.17
Others	30	41.67
Total	72	100

Descriptive statistics were employed to analyze the distribution pattern of the collected data and evaluate asymmetry by calculating skewness and kurtosis. George and Mallery (2010) asserted that for a normal univariate distribution, it is typically appropriate for the values of skewness and kurtosis to vary from -2 to +2. Hair et al. (2010) have asserted that data is considered normal when skewness is between -2 and +2, and kurtosis is within -7 to +7. The data in Table 2 demonstrates that the skewness of a normal distribution is exactly zero, indicating that any dataset displaying symmetry will possess a skewness value near 0. The skewness values of 0.576, 1.732, 0.894, and 0 for the variables of employment status, occupation, years of experience, and sex signify a right-skewed distribution. The data distribution is uniform and demonstrates asymmetry.

Table 2. Descriptive statistics of job status, occupation, age, and sex distributions of the respondents

Descriptive parameters	*Sex*	Year exp	Occupation	Job Status
Mean	36	18	24	14.4
Standard Error	33	6.81909085	9	6.392182726
Median	36	15	15	6
Mode	#N/A	#N/A	15	3
Standard Deviation	46.66904756	13.6381817	15.58845727	14.2933551
Sample Variance	2178	186	243	204.3
Kurtosis	#DIV/0!	0.74765869	#DIV/0!	-3.291932698
Skewness	#DIV/0!	0.89407435	1.732050808	0.576035516
Range	66	30	27	27

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Minimum	3	6	15	3
Maximum	69	36	42	30
Sum	72	72	72	72
Count	2	4	3	5
Largest(1)	69	36	42	30
Smallest(1)	3	6	15	3
Confidence Level(95.0%)	419.3047562	21.7013905	38.72387457	17.74754444

The opinions of respondents regarding the endorsement of investment in innovative technology within the kola nut industry are illustrated in Figure 1. Twenty-five percent of respondents are likely to recommend investing in novel technology to other stakeholders in the kola nut business, while fifty percent are extremely likely to do so. The results indicated that 50% of respondents are extremely likely to recommend investing in new technology, 25% are likely to recommend investing in new technology, and the remaining 25% are neutral, unlikely, or extremely unlikely to recommend investment. It suggests that there is a significant amount of support, as 75% of respondents (50% + 25%) are in favor of investing in innovative technology. Additionally, half of the respondents are extremely enthusiastic about recommending investment, which suggests that there is potential for growth in the e-kola nut business through the adoption of technology. It results in increased efficiency by streamlining processes, reducing costs, and improving productivity, thereby enhancing competitiveness. The kola nut industry can maintain a competitive edge by implementing innovative technology. Enhanced quality: Consistent quality and food safety standards can be guaranteed through the implementation of new technology.

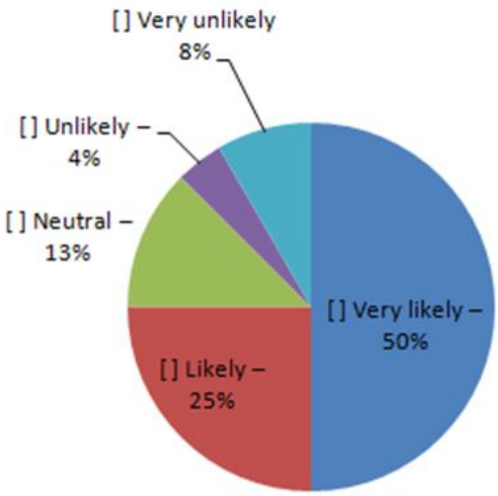

Figure 1: **investing in innovative technologies of the kola nut industry**

Figure 2 illustrates the principal obstacles to the adoption of novel technology in the kola nut industry. The results indicate that the predominant obstacle identified by respondents is the initial investment, with high initial costs cited by 31%. Nearly one-third of respondents also highlight insufficient technical knowledge as a significant barrier, accounting for 27%. Other barriers include the complexity of implementation (17%), limited access to funding (14%), regulatory uncertainty (11%), and miscellaneous factors (1%). It offers insights into cost sensitivity, as substantial initial investments discourage businesses from adopting innovative technologies; the skill gap, characterized by insufficient technical expertise, impedes effective technology integration, while complexity and regulatory uncertainty present considerable obstacles. Financial constraints due to elevated initial costs may hinder small-scale enterprises from adopting new technologies. Additionally, attracting and retaining technically proficient personnel is essential; thus, governments, organizations, or industry partners could offer training, funding, or guidance.

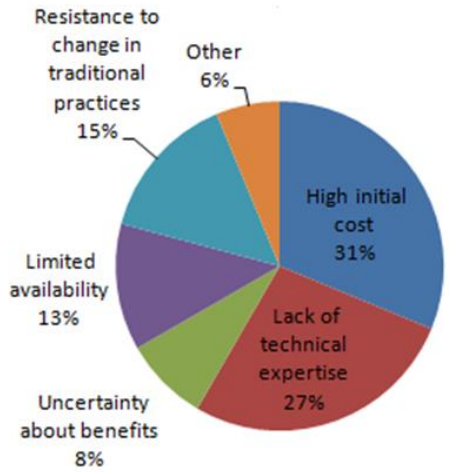

Figure 2: **primary barrier to adopting these innovative technologies**

Figure 3 illustrates the prospective advantages of implementing advanced processing technology in the kola nut industry. The data indicated that the majority of respondents anticipate that new technology will enhance procedures and improve efficiency (30%). Approximately one-third of respondents anticipate greater product quality (28%), with additional benefits including increased productivity (20%), cost reduction (15%), improved food safety (5%), environmental sustainability (2%), and other factors (1%). It provides insights that modern technology can automate operations, minimize waste, and maximize production yields, hence enhancing productivity, efficiency, and quality. Innovative technologies can guarantee uniformity, enhance

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texture, flavor, and nutritional quality, while also yielding cost reductions: optimized processing can diminish energy usage, labor expenses, and material waste. This suggests that enterprises utilizing cutting-edge technologies can surpass their rivals. Superior products can increase market share and draw new customers, while sustainable technologies can improve brand reputation.

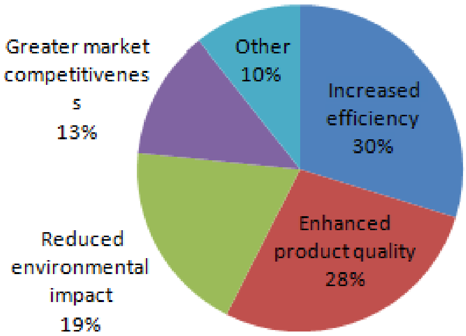

Figure 3: **the potential benefit of adopting innovative processing technologies**

Figure 4 delineates the principal elements affecting the choice to implement new processing technology in the kola nut industry. The findings indicated that the majority of respondents prioritize cost savings and return on investment, with cost-effectiveness at 25%. Nearly one-fifth of respondents regard eco-friendly technologies and environmental benefits at 19%, while the enhancement of product quality is a notable consideration at 18%. Additional factors include increased efficiency at 15%, regulatory compliance at 12%, market demand at 8%, competition at 5%, and other factors at 8%. Cost-effectiveness is a primary concern for organizations, while environmental benefits are gaining significance, and enhancing product quality promotes acceptance. It suggests that enterprises prioritize tangible advantages (cost, efficiency) over inspirational objectives (environmental benefits), while regulatory compliance and market demand also affect adoption decisions, and competition and market pressure propel technology adoption.

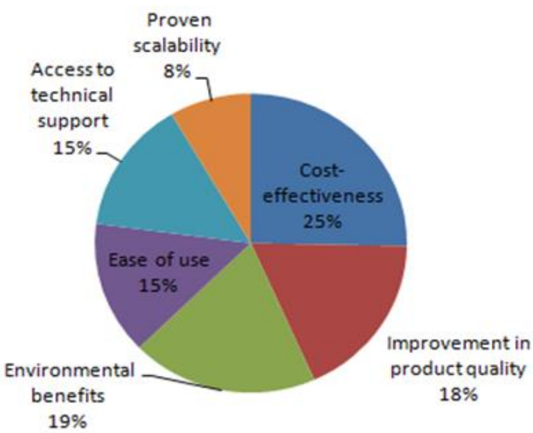

Figure 4: **factors influencing the decision to adopt a new processing technology**

The comprehension of innovative technologies among respondents in the kola nut industry is illustrated in Figure 5. The results indicated that the majority of respondents have a moderate understanding of innovative technologies (33.3%), a quarter of them have an advanced understanding (25%), some respondents lack knowledge about innovative technologies (16%), a small group has expert-level knowledge (10%), and some respondents are unfamiliar with innovative technologies (15.7%). It offers perspectives on the fact that 31.7% of respondents (16% + 15.7%) lack a sufficient understanding. Consequently, training programs could potentially increase adoption rates, and respondents' levels of understanding range from novice to expert. It suggests that the primary objective should be to target respondents with limited or no comprehension, utilizing the expertise of experts (25% + 10%) to provide support and resources to users, and educating others.

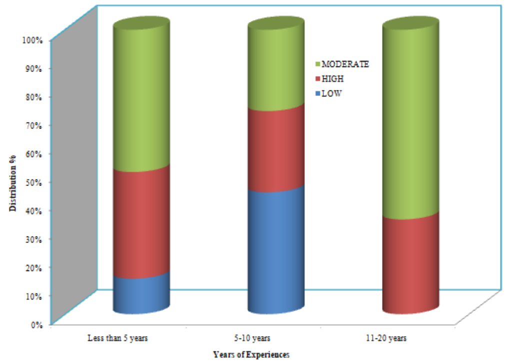

Figure 5: **the understanding of the innovative technologies with rear of experiences**

The data in Figure 5 demonstrates the level of understanding of innovative technologies among respondents in the kola nut industry. The potential interactions between the variables of year of experience and comprehension of using innovative technologies in the kola nut industry were analyzed using ANOVA in the study. The ANOVA distribution is illustrated in Table 1, which serves as evidence of the year of experience and comprehension of the utilization of innovative technologies in the context of kola nut interactions.

Testing of research hypotheses - Hypothesis 1

H0 asserts that the year of experience is not significantly influenced by the comprehension of the utilization of innovative technologies in the kola nut, while H1 asserts that the year of experience is significantly influenced by the comprehension of the utilization of innovative technologies in the kola nut. ANOVA analysis is demonstrated in Table 3 to investigate the interactions between the year of experience and the understanding of using innovative technologies.

Table 3 ANOVA - the interactions between the year of experience and the understanding of using innovative technologies

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Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	24	2	12	1.142857	0.404959	6.944272
Columns	42	2	21	2	0.25	6.944272
Error	42	4	10.5			
Total	108	8				

The decision rule (Table 3) stipulates that H0 is accepted and H1 is rejected when the F-calculated is less than the F-tabulated. The H0 hypothesis is accepted, as the F calculated (1.142857) is less than the F-tabulated (6.944272). The H1 hypothesis, which asserts that the year of experience is significantly influenced by the understanding of using innovative technologies in the kola nut, is rejected.

Testing of research hypotheses - Hypothesis 2

H0 is the assertion that the comprehension of innovative technologies does not significantly influence occupations, while H1 is the assertion that the comprehension of innovative technologies does significantly influence occupations.

The data in Figure 6 demonstrates the level of understanding of innovative technologies among respondents in the kola nut industry. The potential interactions between the variables of occupation and understanding of using innovative technologies in the kola nut industry were investigated using ANOVA analysis in the study. The ANOVA distribution is illustrated in Table 2, which serves as evidence of occupation and comprehension of the utilization of innovative technologies in the context of kola nut interactions.

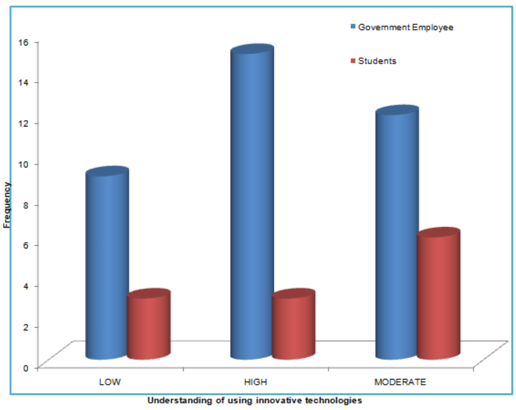

Figure 6: **the understanding of the innovative technologies with occupation**

Testing of research hypotheses - Hypothesis 1

H0 asserts that the occupation is not significantly influenced by the comprehension of the utilization of innovative technologies in the kola nut, while H1 asserts that the occupation is significantly influenced by the comprehension of the utilization of innovative technologies in the kola nut. An analysis of variance (ANOVA) was conducted to investigate the potential interactions between occupation and comprehension of innovative technologies as shown in Table 4.

Table 4 ANOVA - the potential interactions between occupation and comprehension of innovative technologies

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	12	2	6	1	0.5	19
Columns	96	1	96	16	0.057191	18.51282
Error	12	2	6			
Total	120	5				

The decision rule (Table 4) indicates that if the F-calculated is less than the F-tabulated, H0 is approved and H1 is refused. Since the calculated F value (1.0) is less than the tabulated F value (19), the null hypothesis (H0) is accepted, indicating that occupations are not significantly influenced by the comprehension of innovative technologies in kola nut production, while the alternative hypothesis (H1) is rejected, which posits that occupations are significantly affected by this understanding.

Figure 7 reveals the primary challenges faced by kola nut processors with their current methods. The findings revealed that most respondents struggle with inconsistent or poor product quality, 1. product quality (24%), high operating costs are a significant challenge, cost (22%), processors worry about the ecological effects of their methods, environmental impact (20%) and other challenges include efficiency (15%), labor (10%), regulatory compliance (5%), scalability (4%) and other (1%). It gives insights that processors struggle to maintain consistent quality, and high costs erode profit margins. It implies that quality enhancement technologies can improve product consistency, cost-saving innovations can boost profitability and Eco-friendly technologies can reduce environmental footprint.

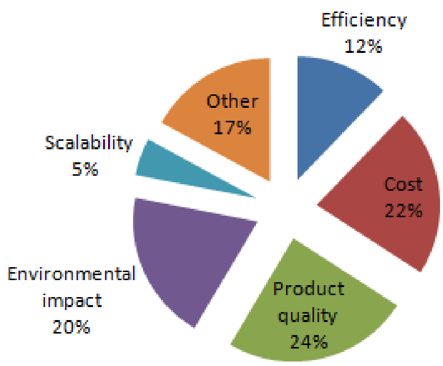

Figure 7: **the primary challenge they face with their current processing methods**

The present processing methods for kola nuts are illustrated in Figure 8. The results indicated that the majority of

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respondents rely on traditional sun drying (38%), a significant proportion use oven drying (22%), a small group use solvent extraction (5%), other methods (21%), freeze-drying (2%), and supercritical CO_2 extraction (2%). Only a small group use microwave drying (10%). It reveals that traditional methods, such as sun drying and oven drying, are widely used, while emerging technologies, such as microwave drying and solvent extraction, are less common. Diverse industry practices are demonstrated by the utilization of numerous processing methods. It suggests that traditional methods may result in quality inconsistencies, but the adoption of recent technologies (e.g., microwave, freeze-drying) can enhance efficiency and quality. Guarantee that solvent extraction and other methods adhere to regulatory compliance safety standards.

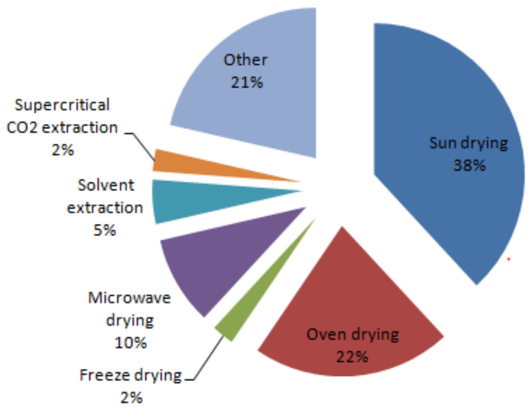

Figure 8: **the processing method currently used for kola nuts**

Conclusion

The kola nut industry is currently at a juncture, as traditional practices are profoundly rooted in culture and are being increasingly supplemented by modern technological advancements. The following conclusions were derived from this study, which investigated the perceptions and implementation of innovative processing techniques, including freeze drying, microwave drying, and supercritical carbon dioxide extraction: Technology has the potential to drive development in the e-kola nut industry. Businesses are discouraged from implementing innovative technologies due to the substantial initial investments required. Modern technology has the capacity to optimize production yields, reduce waste, and automate operations. Organizations prioritize cost-effectiveness, while environmental advantages are becoming increasingly significant, and product quality improvement fosters consumer acceptability. Training programs have the potential to increase the rate of adoption. Maintaining consistent quality is a challenge for processors, and the high costs erode profit margins. Traditional methods, including oven drying and sun drying, are frequently employed, while emerging technologies, including solvent extraction and microwave drying, are less prevalent.

The findings are useful for technology providers, industry associations, policymakers, managers, and business owners. It is recommended that stakeholders invest in staff training and development programs, work with technology providers to ensure effective implementation, and involve regulatory organizations to clarify regulations and guidelines. Business owners and managers should invest in automation and process optimization technology, as well as quality assurance and monitoring tools. Business owners and administrators should consider the potential savings, environmental effect, and improvements in product quality. Managers should undertake training needs assessments, create tailored training programs, create knowledge-sharing platforms, and work with technology providers to get help. Stakeholders should look into sustainable processing methods, quality control procedures, regulatory upgrades, and effective dehydrating technologies. It is recommended that stakeholders use sustainable practices, study cost-saving technology, and invest in quality control procedures.

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