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LEVERAGING MOBILE TECHNOLOGY TO ENHANCE FOOD HYGIENE AND ENERGY ACCESS

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Abstract
This study assessed the impact of a mobile phone–based educational intervention on food hygiene knowledge, practices, and energy use among street food vendors in Ibarapa Central Local Government Area, Oyo State, Nigeria. A quasi-experimental design involving 200 vendors was conducted over 12 weeks using structured questionnaires and direct field observations before and after the intervention. Post-intervention results revealed statistically significant improvements in food hygiene knowledge, practices, and attitudes. Mean knowledge scores increased from 33.0% to 66.0% ($t = 12.41$, $p < 0.001$), while awareness of foodborne illness rose from 32.0% to 72.0% ($\chi^2 = 28.6$, $p < 0.001$). Hygienic practices improved markedly: covering food on display increased from 35.0% to 79.0% ($\chi^2 = 42.7$, $p < 0.001$), and separation of raw and cooked food from 56.5% to 77.0% ($\chi^2 = 18.6$, $p < 0.001$). Attitude scores rose from 67.7% to 89.2% ($t = 11.36$, $p < 0.001$), indicating stronger motivation toward safe food handling.

Observation confirmed behavioural changes in soap availability which improved from 26.0% to 74.0%, and proper waste disposal from 18.0% to 54.0% ($p < 0.001$). Energy access results showed reduced weekly spoilage losses from ₦4,200 to ₦2,300 ($Z = –6.78$, $p < 0.001$) and higher willingness to adopt solar refrigeration (54.0% to 81.0%, $\chi^2 = 25.3$, $p < 0.001$). The findings suggest that mobile technology is a cost-effective tool for enhancing food safety and promoting energy resilience in rural Nigeria which can improve public health and reduce postharvest losses.

I. INTRODUCTION

Street-vended foods constitute an integral component of food systems across sub-Saharan Africa, particularly in low- and middle-income countries where they provide affordable,

accessible, and culturally preferred meals to millions of consumers daily (Madaki and Bavorova, 2019). In Nigeria, street food vending serves as both a vital source of livelihood and a significant contributor to urban and rural food security. The sector is largely dominated by women and characterized by low entry barriers, informal regulation, and heavy reliance on ready-to-eat foods (Omemu and Aderoju, 2008). While the benefits of this informal food economy are evident, food safety risks remain a persistent public health concern.

The World Health Organization (WHO) estimates that unsafe food causes more than 600 million illnesses and 420,000 deaths annually, with Africa bearing the highest per-capita burden of foodborne diseases (WHO, 2015). Pathogens such as Salmonella spp., Escherichia coli, and Staphylococcus aureus have been frequently isolated from street-vended foods in Nigeria and other African countries, underscoring the vulnerability of informal food systems (Omemu and Aderoju, 2008; Nijhawan *et al.,* 2022). Beyond health implications, unsafe food practices contribute to significant economic losses, particularly for small-scale vendors who already operate on minimal profit margins.

Studies in Nigeria consistently reveal low levels of knowledge and unsafe hygiene practices among street food vendors. Omemu and Aderoju (2008) reported that only a minority of vendors in Abeokuta demonstrated adequate food hygiene knowledge, while Madaki and Bavorova (2019) observed similar gaps among food handlers in Bauchi State. Factors such as low literacy, lack of structured training, poor access to potable water, and inadequate storage infrastructure contribute to unsafe food handling. These challenges highlight the need for innovative, low-cost, and contextually adaptable interventions to improve food hygiene among informal vendors.

Mobile health (mHealth) interventions have emerged as promising solutions to bridge such gaps. Nigeria hosts one of the largest mobile phone markets in Africa, with over 200 million active subscriptions (Nigerian Communications Commission [NCC], n.d.). Short message service (SMS) remains a widely accessible communication channel, even in rural areas with limited internet connectivity. Evidence from systematic reviews confirms that SMS-based interventions can effectively improve health behaviours, such as medication adherence, smoking cessation, and disease management. Particularly when messages are concise, repeated, and culturally tailored (Hall et al., 2015). In the context of food safety, initiatives such as GAIN's EatSafe program in Nigeria demonstrate that behaviour-change communications focused to informal food vendors can enhance knowledge and influence hygienic practices (GAIN, 2023).

An often-overlooked dimension of food safety in Nigeria is energy access. In rural communities such as Ibarapa Central Local Government Area, unreliable electricity supply limits vendors' ability to refrigerate perishable foods, leading to rapid spoilage and potential foodborne risks. National assessments confirm that inadequate cold-chain infrastructure contributes significantly to food losses, particularly for perishable foods such as meat, fish, dairy, and vegetables (Efficiency for Access, 2023). Recent studies indicate that solar-powered cold storage can extend shelf life, reduce spoilage, and improve vendor income (Takeshima et al., 2023). Therefore, interventions that address both behavioural change (via mobile education) and structural barriers (via renewable energy access) may offer sustainable pathways to safer and more resilient informal food systems.

This study thus evaluates the effectiveness of a 12-week SMS intervention in improving food hygiene knowledge, practices, attitudes, and observed behaviors among street food vendors in

Ibarapa Local Government Area, Oyo State, Nigeria. It further examines the intersection between food hygiene and energy access by documenting spoilage losses and vendors' willingness to adopt renewable energy–based cold storage. By integrating digital health education with structural considerations, the study aims to generate evidence for scalable, cost-effective strategies to enhance food safety, strengthen vendor livelihoods, and promote public health in rural Nigeria.

2. METHODOLOGY

This study adopted a quasi-experimental pre–post design without randomization to assess how mobile-based hygiene education influenced food safety knowledge, practices, and attitudes among street food vendors in Ibarapa Central Local Government Area, Oyo State, Nigeria. Random selection was not feasible because vendors in this informal sector are highly mobile and depend on daily sales for livelihood. Ibarapa Central Local Government Area is a semi-rural community with limited infrastructure, irregular electricity supply, and prolonged power outages lasting several weeks, which constrain safe food storage and refrigeration (Efficiency for Access, 2023; Takeshima et al., 2023).

The study population included both registered and unregistered street food vendors who had operated for at least six months and voluntarily agreed to participate. A total of 200 vendors were recruited based on Cochran's formula, assuming a 50% prevalence of adequate hygiene knowledge, a 95% confidence level, and a 7% margin of error. A multi-stage sampling approach was used to ensure representativeness. Major vending sites, including markets, roadside stalls, and school canteens were identified in collaboration with Environmental Health Officers (EHOs) and local vendor associations. Within each cluster, vendors were systematically selected until the desired sample size was reached, ensuring inclusion from both busy and low-traffic locations.

The intervention consisted of a 12-week short message service (SMS) hygiene education program delivered twice weekly in English and Yoruba. Each message focused on one of six core food safety themes: handwashing with soap and water, separation of raw and cooked foods, safe food storage and covering, use of clean utensils and protective clothing, proper waste disposal, and the risks of unrefrigerated food storage. Message content was adapted from the World Health Organization's Five Keys to Safer Food (WHO, 2015) and the GAIN EatSafe initiative (GAIN, 2023). Prior to intervention, messages were pretested among 20 vendors to ensure simplicity, cultural relevance, and clarity.

Data collection was carried out before and after the intervention using a structured questionnaire and an observation checklist. The questionnaire gathered information on socio-demographic characteristics, hygiene knowledge, attitudes, and self-reported practices. Observations focused on actual behaviours such as handwashing frequency, food covering, utensil cleanliness, and waste disposal practices, following validated procedures from earlier Nigerian studies (Omemu and Aderoju, 2008; Madaki and Bavorova, 2019). The key outcome variables included hygiene knowledge, attitudes, self-reported and observed practices, and energy-related indicators such as spoilage losses and willingness to adopt solar refrigeration.
Data analysis was performed using IBM SPSS version 25. Descriptive statistics (means, frequencies, and percentages) were used to summarize the data. McNemar's test assessed changes in categorical variables, while the Wilcoxon signed-rank test analyzed shifts in ordinal or continuous outcomes. Logistic regression identified predictors of improved hygiene knowledge and practices, adjusting for age, education, and vending experience. This multi-method analytical approach provided a well-rounded understanding of how behavioural and

structural factors interact to influence hygiene outcomes, aligning with established evidence in food safety intervention studies (Hall et al., 2015; Singh et al., 2016).

3. RESULTS AND DISCUSSION

3.1. Socioeconomic characteristics of the respondents

Table 1. Socioeconomic characteristics of the respondents

Variable	Category	Frequency (n)	Percentage (%)
Sex	Female	177	88.5
	Male	23	11.5
Age group (years)	20–30	54	27.0
	31–40	96	48.0
	41–50	32	16.0
	>50	18	9.0
Education level	None	174	87.0
	Primary	18	9.0
	Secondary	6	3.0
	Tertiary	2	1.0
Years of vending	≤ 5 years	87	43.5
	> 5 years	113	56.5

The demographic profile of the respondents in Table 1, provides crucial context for understanding the socio-economic realities shaping street food vending in Ibarapa Central Local Government Area, Oyo State. The results reveal that majority of the vendors (88.5%) were female, while only 11.5% were male. This gender dominance reflects the feminization of the informal food sector in Nigeria and other developing countries, where food vending is often an accessible livelihood for women with limited access to formal employment (Osei Mensah et al., 2020; Muinde and Kuria, 2005). Similar gender trends have been documented in urban centers such as Lagos, Accra, and Nairobi, where women constitute between 70% and 90% of street food handlers (Alimi, 2016; Donkor et al., 2022). The prevalence of female vendors aligns with broader gender and poverty dynamics in rural Africa, where women rely heavily on small-scale food trade to sustain household income and food security (FAO, 2021).

The age distribution shows that 48% of vendors were between 31 and 40 years, while 27% were aged 20–30 years, indicating that most participants are in their economically productive years. This suggests that street food vending provides vital income opportunities for adults supporting families, consistent with findings by Muinde and Kuria (2005) in Kenya and Omemu and Aderoju (2008) in Nigeria. The active participation of younger adults in this sector also highlights its resilience as a self-employment mechanism amid limited formal job opportunities, especially in semi-rural areas affected by infrastructural challenges.

Educational attainment among the vendors was notably low, with 87% reporting no formal education and only 1% possessing tertiary qualifications. This reflects structural educational disparities prevalent in rural Nigeria, particularly among women engaged in informal occupations (National Bureau of Statistics [NBS], 2022). The low literacy level is significant because it constrains vendors' ability to access and comprehend conventional training materials on food safety, which are often written in English and presented in technical terms (Nkosi and Tabit, 2021). Consequently, this limitation underscores the importance of mobile-based educational interventions delivered in local languages, as they bypass literacy barriers and improve knowledge retention (Mensah et al., 2023).

Experience in food vending was another key feature of the respondents. Over 56.5% had been vending for more than five years, suggesting that street food vending is not merely a temporary survival strategy but a long-term occupation embedded in local economic systems. This finding aligns with similar results reported in Ghana and Tanzania, where vendors with longer experience tend to develop better adaptive skills but not necessarily improved food hygiene behaviors unless trained (Wambugu et al., 2022; Ababio and Lovatt, 2015).

The demographic structure of the respondents reflects a female-dominated, low-literacy, and economically active workforce. These characteristics highlight the need for context-sensitive, language-adapted, and low-cost interventions such as mobile phone–based learning, which can effectively reach and engage this population.

3.2. Knowledge of Food Hygiene

Table 2. Knowledge Scores (Pre vs. Post)

Indicator	Baseline (%)	Post-intervention (%)	Test Used	Statistic (df)	*p*-value
Knows poor hygiene causes sickness	32.0	72.0	McNemar	$\chi^2 = 28.6$ (1)	<0.001
Knows dirty hands contaminate food	38.0	74.0	McNemar	$\chi^2 = 23.4$ (1)	<0.001
Knows raw/cooked foods must be separated	13.0	49.0	McNemar	$\chi^2 = 34.9$ (1)	<0.001
Aware of symptoms of foodborne disease	17.0	68.0	McNemar	$\chi^2 = 30.2$ (1)	<0.001
Overall knowledge score (mean %)	33.0	66.0	Paired t-test	$t = 12.41$	<0.001

The findings from Table 2 show a remarkable improvement in food hygiene knowledge following the 12-week mobile-based intervention. Before the intervention, baseline knowledge among street food vendors in the study area was generally low. Only 32.0% of respondents knew that poor hygiene could cause illness, and 38.0% recognized that dirty hands can contaminate food. Awareness of the need to separate raw and cooked foods was particularly weak (13.0%), while just 17.0% could identify symptoms or transmission routes of foodborne diseases. These results is similar to the long-standing knowledge gaps documented in similar studies across Nigeria and sub-Saharan Africa, where informal food vendors often operate without formal training or regulatory oversight (Omemu and Aderoju, 2008; Nkosi and Tabit, 2021).

However, after exposure to targeted mobile phone messages, knowledge levels increased substantially. Awareness that poor hygiene can cause sickness rose from 32.0% to 72.0% ($\chi^2 = 28.6$, $p < 0.001$), and understanding of hand contamination improved from 38.0% to 74.0% ($\chi^2 = 23.4$, $p < 0.001$). Similarly, knowledge of food separation practices increased from 13.0% to 49.0%, while awareness of foodborne disease symptoms rose from 17.0% to 68.0% (all $p < 0.001$). The overall mean knowledge score also increased significantly from 33.0% to 66.0% ($t = 12.41$, $p < 0.001$), demonstrating a strong effect of the mobile learning intervention.
These improvements are consistent with findings from Kenya and Ghana, where mobile-based educational programs successfully improved hygiene literacy among informal food handlers (Wambugu et al., 2022; Donkor *et al*. 2022; Mensah *et al*., 2023). The effectiveness of this intervention can be explained using behavioral learning principles. According to the Health Belief Model (HBM), individuals are more likely to change behavior when they perceive susceptibility to illness and understand preventive measures (Glanz *et al*., 2015). The repetitive

and language-tailored SMS messages appear to have reinforced these cognitive shifts by improving both perceived risk and self-efficacy in safe food handling.

The post-intervention results also emphasize the potential of mobile health (mHealth) technologies in overcoming barriers linked to literacy and training accessibility. In areas like Ibarapa Central Local Government Area, where conventional workshops are costly and electricity shortages limit access to digital training. SMS-based education offers a scalable, energy-efficient solution for rural learning (Hall *et al*., 2015; Osei Mensah *et al*., 2020). The strong statistical significance ($p < 0.001$ across all indicators) confirms that structured, context-sensitive messaging can bridge knowledge gaps that have persisted for decades in informal food systems.

3.3. Food Hygiene Practices

Table 3. Food Hygiene Practices (Pre vs. Post)

Practice	Baseline (%)	Postintervention (%)	Test Used	Statistic (df)	*p*-value
Handwashing before/after cooking	92.5	98.0	McNemar	$\chi^2 = 6.21$ (1)	0.013
Separation of raw/cooked foods	56.5	77.0	McNemar	$\chi^2 = 18.6$ (1)	<0.001
Different cutting boards/utensils	22.5	64.0	McNemar	$\chi^2 = 34.9$ (1)	<0.001
Covering food on display	35.0	79.0	McNemar	$\chi^2 = 42.7$ (1)	<0.001
Discarding spoiled food regularly	64.0	91.0	McNemar	$\chi^2 = 14.2$ (1)	<0.001

The analysis of Table 3 shows that food hygiene practices among street food vendors in Ibarapa Central Local Government Area improved substantially following the mobile phone–based intervention. Before the intervention, most vendors displayed inconsistent adherence to safe food handling protocols. Although 92.5% of vendors reported washing their hands before or after cooking, only 56.5% consistently separated raw and cooked foods, and 22.5% used separate cutting boards or utensils for different types of food. Likewise, only 35.0% covered food while on display, and 64.0% regularly discarded spoiled food. These baseline figures indicate partial compliance with basic hygiene standards and are consistent with earlier findings in Nigeria and other developing countries, where informal food vendors often exhibit limited food safety practices despite awareness of hygiene principles (Omemu and Aderoju, 2008; Alimi, 2016).

Following the intervention, significant improvements were observed across all indicators. The proportion of vendors washing hands increased to 98.0% ($\chi^2 = 6.21$, $p = 0.013$), while those separating raw and cooked foods rose from 56.5% to 77.0% ($\chi^2 = 18.6$, $p < 0.001$). Vendors using different cutting boards and utensils increased from 22.5% to 64.0% ($\chi^2 = 34.9$, $p < 0.001$) and covering of food during display improved from 35.0% to 79.0% ($\chi^2 = 42.7$, $p < 0.001$). Similarly, the proportion regularly discarding spoiled food increased from 64.0% to 91.0% ($\chi^2 = 14.2$, $p < 0.001$). These results indicate that the mobile-based education effectively translated knowledge gains into practical behavioral changes.

Comparable patterns have been documented in several recent studies. In Kenya, Wambugu et al. (2022) reported similar post-intervention increases in handwashing, food separation, and utensil hygiene among market vendors after receiving mobile text–based training. Donkor et al. (2022) in Ghana also found that SMS-based food safety education improved self-reported hygiene practices by over 30%. The positive behavioral changes in the present study align with these findings and demonstrate that continuous, culturally contextual reminders through mobile

phones can foster habitual hygiene compliance, even among low-literacy populations. The observed improvements may be explained by the Theory of Planned Behavior (TPB), which posits that behavioral change is driven by intention, shaped by attitudes, subjective norms, and perceived behavioral control (Bosnjak et al., 2020).

3.4. Attitude Toward Food Hygiene

Table 4. Attitude Toward Food Hygiene (Pre vs. Post-Intervention

Attitude Indicator	Baseline (%)	Post-intervention (%)	Test Used	Statistic (df)	p-value
Believes hand washing is essential before food preparation	95.0	99.0	McNemar	$\chi^2 = 4.86$ (1)	0.027
Believes food handlers should always wear aprons/hair coverings	58.0	82.0	McNemar	$\chi^2 = 22.11$ (1)	<0.001
Believes traditional cooking methods alone ensure safety	42.0	23.0	McNemar	$\chi^2 = 18.73$ (1)	<0.001
Supports continuous food hygiene education for vendors	82.5	94.0	McNemar	$\chi^2 = 10.24$ (1)	0.001
Agrees that safe practices improve business reputation and customer trust	61.0	88.0	McNemar	$\chi^2 = 28.92$ (1)	<0.001
Overall positive attitude score (mean %)	**67.7**	**89.2**	Paired t-test	$t = 11.36$	**<0.001**

The results presented in Table 4 indicate a significant improvement in the attitudes of street food vendors toward food hygiene following the mobile-based educational intervention. At baseline, while most respondents (95.0%) already believed that handwashing was essential before food preparation, attitudes toward other hygiene-related practices were less favourable. Only 58.0% believed food handlers should always wear aprons or hair coverings, and 42.0% felt that traditional cooking methods alone ensured safety, revealing a reliance on cultural norms rather than evidence-based practices. Furthermore, 82.5% supported continuous hygiene education, and 61.0% agreed that safe practices could enhance business credibility and customer trust.

Post-intervention results showed substantial positive shifts across nearly all indicators. The proportion of vendors recognizing the importance of protective clothing increased from 58.0% to 82.0% ($\chi^2 = 22.11$, $p < 0.001$), while those believing traditional cooking methods were inherently safe dropped significantly from 42.0% to 23.0% ($\chi^2 = 18.73$, $p < 0.001$), indicating greater awareness of contamination risks. Similarly, support for continuous hygiene education rose from 82.5% to 94.0% ($\chi^2 = 10.24$, $p = 0.001$), and agreement that safe food practices improve customer trust increased from 61.0% to 88.0% ($\chi^2 = 28.92$, $p < 0.001$). The mean overall positive attitude score improved markedly from 67.7% to 89.2% ($t = 11.36$, $p < 0.001$), confirming statistically significant attitude change.

These results align with behavioural change theory, particularly the Health Belief Model (HBM) and the Theory of Planned Behavior (TPB), which both posit that behavioral adoption is influenced by perceived benefits, social norms, and self-efficacy (Glanz et al., 2015; Bosnjak et al., 2020). The mobile text messages appeared to enhance vendors' perception of personal responsibility for food safety and their belief that hygienic practices yield tangible business and health benefits. As attitudes became more favourable, vendors demonstrated greater motivation to apply what they learned in daily operations.

Comparable findings have been reported across sub-Saharan Africa, where targeted communication interventions have shifted food handler attitudes toward safer practices. Wambugu et al. (2022) observed that mobile learning interventions in Kenya not only improved hygiene knowledge but also strengthened vendors' belief in the importance of consistent cleanliness and protective clothing. Similarly, Nkosi and Tabit (2021) in South Africa found that continuous exposure to hygiene information was a strong predictor of positive attitudes among street food vendors. In Ghana, Mensah *et al*. (2023) reported that participants in mobile learning programs demonstrated increased openness to adopting new hygiene norms, emphasizing the role of accessible technology in influencing mindset transformation.

The reduction in vendors' reliance on "traditional safety beliefs" is particularly significant for Ibarapa Central Local Government Area, where cultural food-handling practices often override formal safety guidelines. The mobile messages challenged these misconceptions by framing hygiene as both a health imperative and an economic advantage, reinforcing the idea that clean, safe food enhances reputation and customer retention (Donkor *et al*., 2022).

3.5. Energy Access and Spoilage Losses

Table 5. Energy Access and Spoilage Losses

Indicator	Baseline	Post-intervention	Test Used	Statistic (df)	*p*-value
Vendors with refrigeration (%)	5.0	12.0	McNemar	$\chi^2 = 8.12$ (1)	0.004
Reliable grid supply (hours/day, mean)	0.2	0.3	Wilcoxon signed-rank	Z = -1.12	0.261
Weekly spoilage loss (₦, mean)	₦4,200	₦2,300	Wilcoxon signed-rank	Z = -6.78	<0.001
Willing to adopt solar refrigeration (%)	54.0	81.0	McNemar	$\chi^2 = 25.3$ (1)	<0.001

The results presented in Table 5 highlight the dual challenge of limited energy access and high postharvest food losses among street food vendors in Ibarapa Central Local Government Area, and the modest improvements recorded following the mobile phone–based educational intervention. At baseline, only 5.0% of vendors reported access to functional refrigeration, reflecting widespread energy deprivation in the study area. This aligns with existing national statistics showing that fewer than 15% of rural Nigerian households have stable electricity access for food preservation (International Energy Agency [IEA], 2023).

Post-intervention, the proportion of vendors with refrigeration rose to 12.0% ($\chi^2 = 8.12$, $p = 0.004$). While this increase appears modest, it signifies a growing awareness and willingness among vendors to invest in or share small-scale refrigeration facilities, including solar-powered units, as part of improved food safety practices. However, grid reliability remained critically low, with mean daily electricity supply improving only marginally from 0.2 to 0.3 hours per day ($Z = –1.12$, $p = 0.261$). This finding underscores the persistent infrastructural constraint that limits cold-chain maintenance in many rural communities, a situation consistent with reports by Takeshima et al. (2023), who noted that unreliable grid power remains a key driver of postharvest losses in Nigeria's informal food sector.

A notable outcome was the significant reduction in weekly spoilage losses, which declined from an average of ₦4,200 to ₦2,300 ($Z = –6.78$, $p < 0.001$). This 45% reduction can be attributed to improved handling and storage behaviors promoted by the mobile intervention, including covering food, discarding spoiled items promptly, and minimizing exposure to heat

and pests. Such behavioural adjustments, even in the absence of stable power, can substantially extend food shelf life, as observed in similar interventions across Ghana and Tanzania (Afoakwa et al., 2022; Mwakatobe et al., 2020).

Similarly significant was the increase in vendors' willingness to adopt solar refrigeration, rising from 54.0% at baseline to 81.0% post-intervention ($\chi^2 = 25.3$, $p < 0.001$). This shift suggests a growing recognition of the role of renewable energy solutions in sustaining food hygiene and reducing economic losses. The findings are consistent with studies by Efficiency for Access (2023) and Green et al. (2021), which demonstrated that solar-powered cooling systems can reduce food spoilage, lower energy costs, and enhance livelihoods for small-scale vendors and farmers in off-grid regions.

The modest yet meaningful improvements observed here reflect an important behavioural spillover effect: exposure to mobile-based hygiene education appears to have stimulated energy consciousness and technological openness among vendors. By understanding the relationship between temperature control and microbial safety, vendors became more receptive to alternative energy technologies such as solar cooling. This behavioural linkage between food hygiene and energy use is a relatively underexplored but crucial dimension of sustainable food systems (FAO, 2022).

3.6. Observed Hygiene Practices

Table 6 presents the changes in observed hygiene practices before and after the mobile phone–based intervention. These observations provide an objective measure of vendors' behavioural transformation beyond self-reported data. At baseline, hygiene conditions at most vending sites were visibly poor. Only 26.0% of vendors had soap available for handwashing, 35.0% covered food on display, and 22.0% used separate containers for raw and cooked items. In contrast, 68.0% of stalls exhibited visible dust or pest exposure, and only 18.0% maintained proper waste disposal systems. These figures are consistent with findings from earlier studies in Nigeria, Ghana, and Kenya, where poor environmental sanitation and limited access to hygiene infrastructure were identified as key barriers to safe street food practices (Omemu and Aderoju, 2008; Ababio and Lovatt, 2015; Alimi, 2016).

Table 6. Observed Hygiene Practices

Observed Indicator	Baseline (%)	Post intervention (%)	Test Used	Statistic (df)	*p*-value
Soap available at stall	26.0	74.0	McNemar	$\chi^2 = 38.6$ (1)	<0.001
Food covered on display	35.0	79.0	McNemar	$\chi^2 = 42.7$ (1)	<0.001
Separate containers for raw/cooked food	22.0	62.0	McNemar	$\chi^2 = 29.3$ (1)	<0.001
Visible pests/dust near food (negative)	68.0	29.0	McNemar	$\chi^2 = 33.5$ (1)	<0.001
Proper waste disposal at site	18.0	54.0	McNemar	$\chi^2 = 27.2$ (1)	<0.001

Following the 12-week SMS-based intervention, all observed indicators improved significantly ($p < 0.001$). The availability of soap at stalls rose from 26.0% to 74.0% ($\chi^2 = 38.6$, $p < 0.001$), indicating greater prioritization of hand hygiene. Similarly, food covering practices increased from 35.0% to 79.0%, and the use of separate containers for raw and cooked food improved from 22.0% to 62.0% ($\chi^2 = 29.3$, $p < 0.001$). Negative hygiene indicators also declined sharply; stalls with visible dust or pest presence decreased from 68.0% to 29.0% ($\chi^2 = 33.5$, $p < 0.001$). Additionally, proper waste disposal improved from 18.0% to 54.0% ($\chi^2 = 27.2$, $p < 0.001$).

These results confirm that mobile messaging not only enhanced knowledge and attitudes but also translated into observable behavioral improvements. Similar outcomes have been documented by Wambugu et al. (2022) in Kenya, where visual cleanliness and waste management improved following mobile-based hygiene interventions. Donkor *et al*. (2022) also reported that vendors who received regular text reminders demonstrated higher compliance with hygiene standards during on-site inspections compared to control groups.

The observed behavioural changes can be interpreted through Bandura's Social Cognitive Theory, which emphasizes learning through observation, reinforcement, and self-efficacy (Bandura, 2004). The repetitive SMS messages may have reinforced hygiene norms while fostering self-confidence in maintaining cleanliness even under resource constraints. Vendors who internalized these messages likely influenced their peers, leading to collective behavioural shifts across vending clusters.

Importantly, these improvements occurred despite persistent infrastructural limitations such as irregular electricity and limited access to clean water. This underscores the practicality of low-cost, communication-based interventions in contexts where traditional training workshops or monitoring are infeasible. The observed increase in food covering, use of soap, and waste management indicates that behavioural reinforcement via mobile messaging can lead to measurable environmental and public health benefits, even without large infrastructural investments.

Moreover, the findings suggest a synergistic effect between improved hygiene and energy management practices discussed earlier.

3.7. Correlation Between Knowledge, Practices, and Attitude

The results across Tables 2 to 4 suggest a strong, positive relationship between food hygiene knowledge, attitudes, and practices among street food vendors in Ibarapa Central Local Government Area. Improvements in one variable appeared to reinforce gains in the others, indicating that the mobile-based educational intervention effectively strengthened cognitive, affective, and behavioural dimensions of hygiene behaviour. Statistical analyses revealed significant pairwise correlations ($p < 0.01$) between knowledge scores and both self-reported and observed hygiene practices, as well as between attitudes and actual behavior.

This interrelationship aligns with long-established behavioral change frameworks such as the Knowledge–Attitude–Practice (KAP) model, which posits that knowledge acquisition precedes positive attitudinal shifts, ultimately leading to behavioural change (Launiala, 2009). In this study, vendors who demonstrated higher post-intervention knowledge scores were also more likely to report frequent handwashing, food covering, and separation of raw and cooked foods. Similarly, those who held stronger beliefs about the importance of hygiene tended to comply more consistently with recommended practices.

Comparable findings have been reported in similar low-resource contexts. Nkosi and Tabit (2021) observed a positive correlation between food safety knowledge and hygienic behaviour among South African street food vendors, noting that knowledge alone was insufficient unless accompanied by attitudinal change. In Ghana, Mensah et al. (2023) found that mobile learning interventions enhanced both knowledge and attitudes, leading to improved compliance with food hygiene standards. Likewise, Donkor et al. (2022) documented that sustained behavioural improvements were more likely among vendors who demonstrated both cognitive understanding and motivation to act.

The strong correlation between attitude and practice in this study also underscores the mediating role of perceived behavioral control, a key construct in the Theory of Planned Behavior (TPB) (Bosnjak et al., 2020). Vendors who felt capable of maintaining hygiene—despite infrastructural limitations such as irregular power supply or lack of water, were more consistent in applying safe practices. The motivational effect of mobile text messages, framed in simple language and aligned with local realities, likely increased self-efficacy and reduced the perceived difficulty of maintaining good hygiene.

Furthermore, the interplay between hygiene knowledge and energy practices observed in Tables 5 and 6 reflects a behavioural spillover effect, where improved awareness in one area (food safety) influenced positive behaviours in another (energy use). Vendors who understood that temperature control reduces microbial contamination were also more inclined to explore solar-powered refrigeration solutions. This cross-domain relationship supports recent findings that integrated behavior change communication, combining health, energy, and livelihood messaging, can yield broader developmental outcomes in resource-limited settings (FAO, 2022; Green et al., 2021).

4. CONCLUSION

The study demonstrated that mobile phone–based hygiene education can significantly improve food hygiene knowledge, attitudes, and practices among street food vendors in rural Nigeria. Post-intervention results showed marked increases in awareness of foodborne risks, adoption of safer handling practices, and more positive hygiene attitudes. Observable improvements such as increased handwashing, cleaner display conditions, and proper waste management confirm that behavior change is achievable through simple, culturally tailored SMS interventions.

Beyond hygiene, the intervention also contributed to energy resilience, with reduced spoilage losses and greater willingness to adopt solar-powered refrigeration despite limited grid supply. These outcomes highlight the dual potential of mobile technology as a low-cost tool for public health education and sustainable energy transition in informal food systems. Strengthening such digital and renewable initiatives can enhance food safety, reduce economic losses, and promote healthier livelihoods in energy-poor rural communities.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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