RSM2SNF
Research Supporting African MSMEs
To Provide Safe and Nutritious Food

Title: Is washing enough? Evidence from a study on Nigerian vegetable traders' hygiene and handling practices

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About Research Supporting African MSMEs to Provide Safe and Nutrition Food (RSM2SNF)

The Research Supporting African MSMEs to Provide Safe and Nutritious Food (RSM2SNF) is funded by the Bill and Melinda Gates Foundation. RSM2SNF dives deep into the wholesale, logistics, processing, and retail segments of the value chains of several products, such as fish, tomato, and green leafy vegetables. The goal is to understand the midstream of these food value chains with a focus on Micro, Small and Medium Enterprises (MSMEs), and to inform policies and interventions to support MSMEs in providing safe and nutritious foods at affordable prices. This five-year project (2022–2026) is led by Michigan State University (MSU) working with partners in Nigeria and Tanzania.

Contents

Abstract

Though food vendor hygiene and handling practices are noted as potential sources of contamination, few studies have examined both the drivers of their adoption and their impact on the safety profile of food. This study on fresh vegetable vendors in southwest Nigeria highlights several critical issues related to food safety practices among food vendors. First, while most vendors washed their vegetables, only half adhered to recommended practices such as changing washing water regularly. Properly changing washing water was found to significantly reduce consumer exposure to E. coli, indicating a direct impact on food safety. While good hygiene practices reduce consumer exposure to contaminants, our findings indicate that inadequate toilet facilities, coupled with high use-fees for existing facilities, discourage good hygiene practices among traders. Almost none of the traders in the study had received any formal food safety training which suggests a gap in knowledge and awareness regarding best practices for food handling and hygiene. The study findings reveal the need for increased awareness about hygiene and food safety among food vendors through training programs. In addition, improving market infrastructure, particularly sanitation facilities, and reducing the associated costs could facilitate better adoption and adherence to good food handling practices. Addressing food safety requires a multifaceted approach that includes education, infrastructure improvement, and policy interventions aimed at promoting and sustaining food safety practices among food vendors in Nigeria and similar contexts.

List of Tables

List of Figures

Key words

Vegetable, Traders, handling practices, Food safety, Microbial contaminants

1. Introduction

While food safety remains a global challenge, it is particularly important in low- and middle-income countries (LMICs) that are disproportionately affected by foodborne diseases. LMICs represent 75% of deaths from foodborne illness though they are only 41% of the global population (Havelaar et al., 2015; Grace, 2015; Kirk et al., 2015). In Africa, the per-capita burden of foodborne disease is about 27 times that of Europe or North America, but the health system has limited capacity for diagnosis and treatment (Havelaar et al., 2015; Morhason-Bello et al., 2013; Okoruwa et al., 2021). Traditional food markets are an important source of affordable food and livelihood to many in in developing regions (Avijit Banik et al., 2020; FAO, 2007). However, traditional markets face heightened food safety challenges and a large share of food (raw and ready-to-eat) sold in many African food markets are contaminated at the point of purchase (Jaffee et al., 2018; Paudyal et al., 2017).

In this study, we use evidence from Nigeria to explore the drivers of good hygiene and food handling practices in traditional markets and their impact on the safety profile of fresh vegetables. While there is ample evidence regarding food contamination in traditional markets, majority focus on characterizing the presence of contaminants from food samples tested in laboratories (Imafidon et al., 2018; Eni et al., 2012; Ofor, 2009; Ehimemen, 2019). Others have interacted with food vendors in these markets to understand their level of knowledge about food safety (Adane et al., 2018; Hamed and Mohammed, 2020; Aljasir, 2023; Gemeda et al., 2023) and/or their food handling practices (Mensah et al., 2002; Akoachere et al., 2018; Solomon et al., 2018; Nizame et al., 2019; Aljasir, 2023). To our knowledge, no studies have linked the practices of food vendors in traditional markets to contaminants present in the food being sold by those same vendors. Thus, this study contributes to filling this gap by explicitly exploring the extent and drivers of the adoption of good hygiene and handling practices (by vegetable traders) and its impact on the presence of microbial contaminants; *E. coli*, *Salmonella spp*. and *Bacillus spp.* in fresh vegetables in food markets. These pathogens (*E. coli*, *Salmonella spp*. and *Bacillus spp*) are among the most prevalent foodborne pathogens which are of public health concerns and have been known to cause foodborne diseases such as diarrhoea, typhoid fever, dysentery and cholera, gardiasis, strongyloidiasis, and taeniasis etc. (Orpin et al., 2020). Good hygiene is captured by handwashing with soap and water (after bathroom use) while good handling practices include proper vegetable washing and the method of product display, which have been identified as significant sources of vegetable contamination (Ayensu, 2020).

We focus on Nigeria, a transitioning lower-middle-income country, where food safety concerns are critical and levels of foodborne diseases are high (Jaffee et al., 2018). The costs of mortality

and morbidity in Nigeria is high (estimated at over USD 6 billion in 2016) and noted to be the fourth highest in the world (Jaffee et al., 2019). Approximately 173 million cases of diarrhea and 33,000 deaths are said to be caused by foodborne illness in Nigeria annually, resulting in about USD 1.7 billion in treatment costs, not accounting for lost productivity (Grace et al., 2018). Thus, reducing risk of foodborne illness remains a key challenge for Nigeria though often hindered by limited government capacity and funding for setting and enforcing food safety standards (Grace, 2015, 2016).

Traditional food markets remain the main source of food for consumers across Africa and many low-income consumers depend almost exclusively on traditional markets for nutrient-rich foods like fresh vegetables (Fanzo et al., 2017). However, traditional markets face heightened food safety concerns due to rapid economic, demographic, and dietary changes (that have resulted in the rise of numerous new and/or modified food products), coupled with limited capacities for food safety management (Jaffee et al., 2018). Whether open-air or enclosed, these markets often lack proper infrastructure, access to clean water, sanitary conditions, and adequate storage facilities, posing significant risks for the growth and spread of foodborne hazards (DeWaal et al., 2022; Mensah et al., 2002). Evidence indicates that a substantial portion of the food available in traditional markets is contaminated (Grace, 2015b) and consumer food preparation at home is often not effective in reducing the risk of foodborne illnesses (GAIN, 2020).

Fresh and RTE fruits and vegetables play an important role in a balanced diet. Public health emphasizes the importance of ensuring the safety of such foods given their potential impact on health worldwide regardless of age, race, gender, or income level (Gizaw, 2019). The popularity of fresh and RTE fruit and vegetable consumption is growing due to their ease of preparation, nutritional value (e.g. in salads and smoothies), practicality, and appealing taste (Arslan and Ertürk, 2021; Xu et al., 2015). Fresh vegetables eaten as salads are rich in dietary fiber content, phytochemicals and antioxidants which will contribute to human health and well-being (Finger et al., 2023; Jideani et al., 2021). These foods, requiring no further heating or cooking, can be an important source of key nutrients (particularly minerals and vitamins). However, they are also potentially contaminated with pathogens (e.g. bacteria such as *Bacillus*, *Salmonella*, *Staphylococci*, *Escherichia coli (E. coli)* and *Listeria monocytogenes*) due to earlier mentioned factors such as poor hygiene and environmental factors in food markets.

While the presence of food safety challenges in Nigerian food markets (also common in other low income countries) has been documented (Nordhagen et al., 2022; Nordhagen et al., 2023; Okoruwa & Onuigbo-Chatta, 2021) and evidence of poor handling practices clearly noted (Uchendu, 2018; Faremi et al., 2018; Makinde et al., 2020) , no studies the authors are aware of, have brought together the extent and drivers of good hygiene and food handling practice

adoption among fresh vegetable vendors in Nigerian markets and its link to the presence of microbial contaminants in samples from the same vendors. With information about what drives the adoption of good hygiene and handling practices and also how these practices are linked to the food safety profile of the same handlers, we are able to link trader behavior and practices to food contamination and garner insights on potential mechanisms to encourage the adoption of important practices to increase the safety profile of food in traditional food markets. This study adopts a multidisciplinary approach (leveraging on research tools from the fields of economics and food science) to identify contaminants in fresh vegetables and to understand their drivers. Section 2 describes the materials and methods used for this study while section 3 presents our data and results. Section 4 is a discussion of our findings and Section 5 concludes with some recommendations and policy implications.

2. Data and Methods

2.1 Study area

This study leverages on primary data collected from 9 markets in the 3 senatorial districts or sub counties in Ogun State, Southwest Nigeria in 2023. Ogun State is one of the states that has a significant population density, especially in urban and peri-urban areas and well known for its diverse agricultural activities including vegetable cultivation (Adeleye et al., 2020). Markets and marketing practices vary across Nigeria's diverse geopolitical, economic and cultural conditions. While this study is not nationally representative, the study sample reflects the conditions in many traditional markets in urban areas of southwestern Nigeria, home to over 50 million people (Adekunle, 2012).

2.2 Sample collection and Survey

A total of 509 samples of fresh tomatoes, carrots and cucumbers were collected from traders at 3 different time periods in the same year. Round 1was collected in the early March (the end of the dry season), round 2 was collected in May (the middle of raining season) and round 3 was collected in October (towards the end of the raining season). In addition to collecting basic information about the vendors (e.g. age gender and level of education), we also collected information from the vendors about their handling practices for their vegetables and also about general hygiene. We purchased samples of vegetables from each vendor and transported them in cold storage to the laboratory where they were analyzed for microbial studies at the Nigerian Institute of Medical Research (NIMR), Yaba, Lagos State. This study was approved by the Institutional Review Board of the lead partner University and conducted in accordance with Nigerian legislation and institutional requirements. All participants provided their written informed consent to participate in this study.

2.3. Microbial isolation and identification

For the microbial analysis, one gram of sample was introduced into 9 ml of sterile peptone water in a prelabelled tube. The tube was incubated at 37 ℃ for 24 hours. A small amount of inoculum was streaked onto a MacConkey agar (MAC) plate for *E. coli*, Salmonella shigella (SS) agar plate for *Salmonella spp*., and a Mueller hinton agar plate for *Bacillus spp*. isolation and incubated aerobically at 37 °C for 24 h (Cheesbrough, 1985). The isolates were identified using conventional methods which involve colonial characteristics, gram staining, and biochemical reactions such as carbohydrate fermentation, urease production, and citrate utilization among others as required following bergey's manual of determinative bacteriology (Bergey & Holt, 1994).

2.4. Empirical Analysis using multiple regression analysis

With data from the same vegetable traders over three time periods, equation (1) presents the basic empirical model used to explore the determinants of trader adoption of good hygiene and handling practices and the correlation between these practices and the presence of microbial contaminants in trader's vegetables.

$$(1) \qquad Y_{it} = \propto_i + \boldsymbol{\beta_1} \boldsymbol{X}_{it} + \mu_t + \varepsilon_{it}$$

where Y_{it} is our outcome variable of interest (i.e. whether trader *i* visited in month *t* was using a particular hygiene or handling practice (step 1) and or whether a sample of vegetables purchased from trader *i* in month *t* had a particular contaminant (step2), $\boldsymbol{X}_{it}$ is a vector of trader and market level characteristics that could explain their adoption of the different practices or explain variation in the presence of contaminants in trader vegetable samples (more details below); $\propto_i$ are time-invariant trader-specific effects, μ_t are month fixed effects and ε_{it} is the idiosyncratic error term. $\boldsymbol{\beta_1}$, (our primary focus in this analysis) is a vector parameter to be estimated associated with the trader and market characteristics explaining adoption of good practices and or the presence of microbial contaminants.

For step 1, we estimate Equation 1 using a pooled probit model given the binary nature of our adoption variables (taking a value of one if a trader reported using a particular practice and zero otherwise) and the fact that there was limited variation within traders in their use of the different handling or hygiene over the three survey rounds. However, because we collected vegetable samples from the same traders over three-time periods we are able to explore variation in the presence of the microbial contaminants over seasons (captured by the month that the sample was collected) with a random effects probit model in step 2. We recognize that trader practices in a random effects probit estimation of the impact of handling practices on microbial contaminants does not account for unobservable factors that could be correlated with both traders' adoption of good practices and their likelihood of preventing contamination of the

vegetables they sell. Because most trader characteristics and hygiene/handling practices do not change over time, we are unable to exploit trader variation over time and thus conduct a between trader analysis. We do not interpret our findings as causal but rather as informative associations between trader handling/ hygiene practices and the presence of microbial contaminants, conditional on a rich set of explanatory variables (at trader and market level) that could jointly determine the trader practices and product contamination. We cluster our standard errors at the trader level to account for likely correlation in trader behavior over survey rounds and confirm that our key conclusions in both steps are robust to the use of the pooled estimator or the random effects probit estimator.[1].

For step 1, the five good hygiene/handling practices that we consider are (1) proper washing water changing practices (i.e., changing washing water within the first 4 hours of use), (2) sorting vegetables after purchase (3) using a plastic crate to move or store their products (4) if the trader separates their vegetables and (5) if traders adopt good hygiene practices measured as whether they wash their hands with soap and water after using the bathroom. Recognizing the bias often associated with sensitive questions such as hygiene practices, enumerators were trained on strategies used to ask such questions via a conversation that was non-judgmental. Enumerators also supplemented information from respondents with their observation of trader practices at the markets. The selection of these practices was drawn from a review of the literature on food safety (Rayza et al., 2016; Akoachere et al., 2018; Solomon et al., 2018; Nizame et al., 2019; Hamed & Mohammed, 2020; Aljasir, 2023; Boakye et al., 2023; Magqupu et al., 2024). The explanatory variables considered include trader demographic variables (e.g. gender, age, education) proxies for the scale of the traders last transaction, what product the trader sold (i.e. tomatoes, cucumber or carrots) and market level characteristics such as the location of the market (senatorial district), the number of toilets, the cost for water and or toilet use in the markets.

For step two, we explore three food safety outcomes that are captured by binary variables equal to one if a particular microbial contaminant (*E. coli*, *Salmonella spp*. or *Bacillus spp*.) was found in the sample taken from trader *i* in period *t*. The key explanatory variables in these estimations are the same trader demographic characteristics from step 1 but supplemented with their hygiene

While our study findings are similar when using the random effects probit and logit models, the probit model is our preferred specification because of the ease of interpreting our results as average marginal effects (i.e. the effect of a unit change in a continuous explanatory variable (or its presence/adoption for binary variable) on the probability of each outcome variable being true. In moderate size datasets, the probit link often gives an improved fit over the logit link.

and handling practices, the traded commodity (tomatoes, cucumbers or carrots), the season the samples were collected and the market location.

3. Results

3.1 Descriptive statistics of vegetable traders

Table 1 presents the descriptive statistics of the study sample. Fresh vegetable traders in our sample were on average middle-aged female trader with about 16 years of experience selling vegetables and more than a primary school education. The sample was similarly distributed across the three senatorial districts with a slightly higher share engaged in trading tomatoes (45%) compared to cucumbers (30%) and carrots (25%). Very few traders (<1%) had ever attended a training related to food safety and all traders were in a market with a toilet available within a 5-min walk costing on average about ₦ 65 ($0.10 in 2023 at N700=$1).

3.2 Share of fresh vegetable samples with microbial contamination

Figure 1 presents the share of samples purchased from the traders that tested positive for the presence of a microbial contaminant. First, the share of samples with the identified pathogens were significantly higher at the end of the dry season (round 1) compared to the middle and end of the rainy season. The share of vegetable samples with *E. coli* in March is about double the share from samples collected in May and October. The share of samples with *Bacillus spp.* and *Salmonella spp.* reduced by a third from 30% and 25% to 8% and 2% respectively between March and May. By October, the share of samples with contaminants were still at significantly lower levels compared to March and similar to the share in May. We found that *E. coli* contamination was more prevalent in carrot samples (24%), compared to tomatoes (15%) and cucumbers (8%) while the share of samples testing positive for *Bacillus spp*. was about 26% in cucumber compared to tomatoes (13%) and carrots (2%) and the share of samples with *Salmonella spp*. was on average lower than the share with *E. coli* and *Bacillus spp*. but similar (10%) across all three vegetables.

3.3 Adoption rates of good hygienic and handling practices among traders

Table 2 presents the adoption rates of good hygiene and handling practices. The majority of the vegetable traders in our sample (95%) sort their vegetables after purchase and sold their vegetables on a raised platform (83%) vs. placing it on a sheet/sack on the floor. Eighty percent of the traders in our sample separate their vegetables while on display rather than mix them with other vegetables. We also found that 85% of vegetable traders reported washing their hands with soap and water after using the toilet and 50% changed the water they use to wash their products within 4 hours of first use. Only 10% of traders in our sample reported using plastic crates to store or transport their vegetables.

Comparing adoption rates of the good practices across products (tomatoes, carrots and cucumbers) we find adoption rates for most practices to be higher among tomato traders. For example, while 98% of tomato traders reported good hygiene practices, this was lower among cucumber and carrot traders at 85% and 76% respectively. Similarly, while 75% of tomato traders noted that they changed their washing water within 4 hours of first use, this was done by only 35% of cucumber and carrot traders. The adoption rate of plastic creates was 25% among tomato traders, compared with less than 5% for carrot and cucumber traders.

3.4 Determinants of the adoption of good hygienic practices

Table 3 presents the pooled probit results on the factors associated with the adoption of good handling and hygienic practices among vegetable traders. Five key points emerged. First, we find that male and older traders are more likely to have reported changing their washing water appropriately. Second, we find a non-linear relationship between the quantity of vegetables purchased in the last transaction and the likelihood of changing washing water appropriately. On average, traders who purchased larger quantities were more likely to change their washing water correctly, but this effect reduces as the quantity purchased increases.

Third, we find that female traders and tomato traders were more likely to report good hygiene practices while traders dealing in larger quantities were less likely to have reported good hygiene practices, all things being equal. Traders in a market with more toilets and lower toilet-use-fees are more likely to have reported good hygiene practices. Fourth, we find that traders dealing with larger volumes were less likely to sort and market location matters. Traders in markets in Ogun East were also more likely to report sorting compared to those in Ogun West and Ogun Central. Similar to vegetable sorting, traders with larger volumes purchased in their last transaction were less likely to separate their vegetables for display or use a raised platform. Fifth, we find that the adoption of plastic crates was higher among female and tomato traders consistent with the descriptive statistics. The likelihood of plastic crate use was significantly lower among traders in Ogun East and Ogun Central compared to those in Ogun West.

3.5. Correlation between good handling practices and microbial contamination in vegetable samples

Table 4 presents the results of the random effect probit estimation on the correlation between good hygienic and handling practices and the presence of microbial contaminants in vegetables sold by traders. A key finding is that changing washing water correctly significantly reduces consumer exposure to E.coli. Samples from traders who reported having changed their washing water within 4 hours of first use (as recommended) were associated with about 10 percentage points lower probability of testing positive for *E. coli* (column 1). There was less evidence of handling practices being associated with contaminants for Salmonella spp. and *Bacillus spp*. No

handling practices were associated with Salmonella spp. being present in a sample and the only handling practice found to be significantly associated with the probability of finding *Bacillus spp*. in a sample is the use of a plastic crate to store or transport the vegetables. Using a plastic crate is negatively associated with the probability of finding *Bacillus spp*. in a sample and this is statistically significant at 10%.

Consistent with the descriptive statistics, we find that the probability of finding *E. coli*, *Salmonella spp*. and *Bacillus spp*. in vegetable samples was higher at the end of the dry season (in March) compared to May and October. We also find that the likelihood of microbial contaminants varied with trader characteristics, location and vegetable type. Samples collected from male traders were more likely to have tested positive for the presence of *E. coli*, all things being equal, and this result is statistically significant at 10%. Samples from older traders and those with less trading experience were more likely to be contaminated with *Bacillus spp*. Samples from cucumber traders were about 14% points less likely to have tested positive for *E. coli* compared to samples from carrot traders. Tomato samples were more likely to have tested positive for *Bacillus spp*. compared to carrots.

4. Discussion

While there are several studies of microbial contamination of vegetables, techniques to reduce microbial contamination of fresh vegetables and on knowledge, attitude and practices of vegetable vendors, there is a dearth of literature that relates observed trader practices to contaminant level for vegetables sold by the same vendors as was done in this study.

We found a higher contamination rate (double) for samples collected at the end of the dry season (round 1) compared to the middle and end of the rainy season. This is likely due in part to the higher temperature in the dry season that can facilitate microbial growth. This is similar to studies from Ruiz et al. (1987) who reported that microbial contamination in vegetable samples was higher during the summer and lower during the winter.

Higher counts of pathogens during the dry season could also be driven by limited water source options during that period and the fact that lower water volume in wells or other water bodies are more likely to be contaminated with raw sewage discharge from residential houses and businesses around the markets. This is consistent with findings from other studies noting significantly higher coliform organisms in the dry season than in the wet season (Okafo et al., 2003; Agbogu et al., 2006) and Munize et al. (2020) who found higher rates of *E. coli* during the dry season compared to the rainy season.

We found much higher contamination by *E. coli* compared to the other contaminants. *E. coli* is an important bacterial indicator of water quality and a major public health concern related to

water and food safety (Devane et al., 2020). It is important to note that washing vegetables with water contaminated with *E. coli* can also contaminate the vegetables. Thus E.coli contamination could be driven by multiple factors in traditional markets if washing is not done properly and/or the quality of water is poor. The high contamination by *E. coli* is also supported by studies of Prayoga et al. (2021) who reported a high *E. coli* contamination of vegetables samples obtained from two sites; Huong Chu and Phu Mau in Hue in Vietnam. The high presence of *E. coli* detected in the carrots may be as a result of contamination from animal or human waste residues in the soil (Lynch et al., 2009) and evidence of no or poor washing. This is a particular concern in the Nigerian context where fresh carrots are often consumed directly after purchase from vendors.

Our results indicate significant heterogeneity in the adoption rates of good hygiene and handling practices across the study sample. The adoption of good hygiene practices and all good handling practices except selling their products on a raised platform was much higher among tomato traders compared to cucumbers and traders. While tomatoes are often cooked further in Nigerian cuisine, cucumber and carrots are often consumed fresh and without further processing, with carrots sometimes consumed immediately upon purchase. This indicates the need for particular attention to be paid to encourage the adoption of good hygiene and handing practices by traders of carrots and cucumbers.

The use of plastic crates is generally low; 25% for tomato traders and less than 5% for carrot and cucumber traders. This may be due to the high costs associated with the procurement of plastic crates and the size of the crates (i.e. crates being more amenable to the sale of larger quantities). Familiarity with baskets may also serve as a barrier to the adoption of plastic crates (Aghadi et al., 2020).

A good understanding of hygiene practices is key for preventing contamination and studies have shown that washing vegetables can significantly reduce the fecal level contamination in vegetables (Moris and Brady 2005; Amoah et al. 2006). Our findings reveal that the appropriate wash water changing practices was more common among older traders, male traders and traders who purchased larger quantities of vegetables. However, female traders and tomato traders were more likely to have reported good hygiene practices. This finding of better hygiene practices by female traders is consistent with Mohammed et al. (2020) who observed that female traders observed better hygienic practices than their male counterparts attributed to their experience managing homes.

We find that traders in a market with more toilets and lower toilet-use-fees were more likely to have reported good hygiene practices. Since markets in the study sample typically provide water and soap for handwashing (as part of the toilet-use-fee), these findings suggest that more toilets reduce the transactions cost and effort necessary to access toilets and the associated services.

However, higher costs of using the toilet might encourage traders to use other avenues for defecation such as plastic bags or the bush which are less likely to come with water and soap for handwashing.

The significant correlation between the use of plastic crates and lower levels of *Bacillus spp*. is consistent with the fact that *Bacillus spp*. is a genus designated as a group of soil inhabitants and was likely prevented with the use of plastic crates. The limited impact of handling practices on the presence of *Salmonella spp.* and *Bacillus spp*. is likely due to their generally low presence (5%) in our samples. We find that samples taken from traders who separated their products (rather than mixed them together) were more likely to have *E. coli*. Though this was surprising, it might be because all vegetable traders in our sample sold their vegetables unpackaged. Observation during market visits and anecdotal evidence from interacting with traders indicated that sometimes when products are separated and unpackaged, they entice more consumers to touch them during the product search and negotiation process than when products are all mixed together.

The likelihood of microbial contaminants varies with trader characteristics, location and vegetable type. Samples from older traders and those with less trading experience were more likely to be contaminated with *Bacillus spp*. This might reflect older traders' reluctance to use new practices such as plastic crates or modern packaging that are contrary to their traditional practices and is consistent with the literature that has shown that older people are often less willing to adopt new practices (Özsungur, 2022). However, more experience in trading, conditional on age might reflect the role of trader experience in navigating strategies to keep their products clean and safe over time. Tomato samples were more likely to have tested positive for *Bacillus spp*. compared to carrots. The high contamination of tomato samples by *Bacillus spp*. may be due to the fact that *Bacillus spp*. is predominantly a soil bacterium, and these findings might reflect the inadequacy of current washing practices to completely remove the soil residues on these vegetables.

Together the study revealed a significant correlation between trader handling and hygiene practices and contaminant levels in vegetables sold in Nigerian food markets. However, the adoption of several recommended practices remains low. Efforts to inform and encouraging traders about the importance of properly washing their vegetables and good hygiene practices could significantly reduce consumer exposure to microbial contaminants in fresh vegetables and other RTE food that may only be lightly cooked or consumed raw to preserve their nutrient content. A particularly important in our findings is the fact that it is not just enough to wash vegetables (done by 95% of the sample and almost 100% of tomato traders) but it is important that the water used to wash the vegetables is changed frequently only done by 50% of the sample.

5. Conclusion and policy implications

This study explored the extent and drivers of good hygiene and food handling practices among vegetable traders in traditional food markets in southwest Nigeria. Then we tested if the adoption of these good practices is associated with the safety profile of vegetables. We find that microbial contaminant levels in study samples of vegetables were much higher in the dry season compared to the rainy season. While washing vegetables was done by over 95% of vendors, only half of the vendors used the recommended practice of changing the water used for washing within 4 hours of first use and this recommended practice was significantly associated with a lower likelihood of finding *E. coli* in vegetable samples. The majority of traders sold their fresh vegetables in open spaces and displayed unpackaged on tables or in wheelbarrows exposing them to contaminants by poor hygiene and handling practices of both vendors and customers. As expected, good hygiene practice (washing hands with soap and water after toilet use) was found to be negatively associated with the presence of *E. coli*.

While some good handling practices (such as washing) might seem simple, there are nuances (such as changing the water used to wash frequently) that are very important and should not be overlooked. Though good hygiene and food handling practices can reduce food contamination, almost no traders in our sample had ever received any training on food safety related issues. Efforts to increase awareness, incentives and/or enforced regulations around hygiene and food handling practices are needed. This paper concludes that while improving the safety of vegetables might be complex because of the numerous potential sources of contaminants, there are some relatively simple strategies that can significantly improve the food safety profile of foods in traditional African markets. These include more training/awareness campaigns around good hygiene and food handling practices (e.g. appropriate washing) and the value and types of simple packaging of fresh and RTE products, even without fancy labels to prevent them being touched by customers or vendors.

For the effective adoption of good hygiene and handling practices, market leaders, government and donors should leverage on trader characteristics found to be associated with the adoption of good practices (e.g. gender, age and scale) to design and target trainings and campaigns. For example, governments with limited resources may initially focus on designing and disseminating information on good hygiene and handling practices to groups less likely to adopt the good practices (e.g. males and older traders). In addition, engagement with groups of food

vendors that tend to adopt good practices could inform on strategies to encourage their more widespread adoption. Finally, governments, market leaders and donors can support broader adoption of good hygiene and handling practices via efforts to improve market infrastructure and reduce the associated cost of toilet use in food markets.

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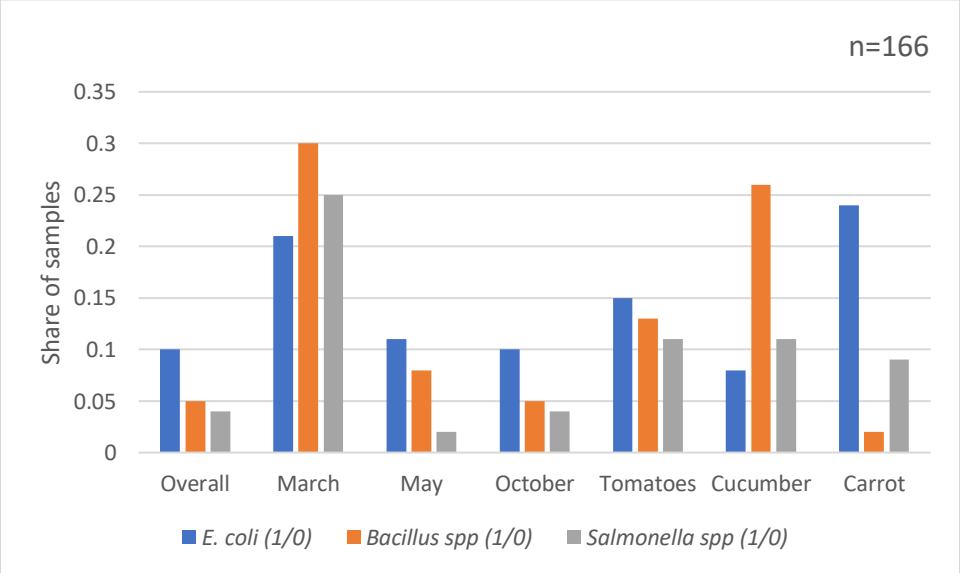
Tables and Figures:

Table 1 Descriptive statistics of vegetable traders in the study sample

LABELS	Mean	Standard Deviation
Male (1/0)	0.40	0.49
Years of selling vegetables	15.76	11.14
Ever attended food safety training (1/0)	0.004	0.06
Cost of using a toilet in the market (naira)	64.36	46.72
Cost of water in the market per liter(naira)	91.05	28.82
Number of toilets in the market	2.89	2.20
Ogun Central	0.36	0.48
Ogun East	0.34	0.47
Ogun West	0.30	0.46
Tomatoes	0.44	0.49
Carrot	0.22	0.42
Cucumber	0.32	0.47
Age in years	39.34	13.04
Quantity of vegetables purchased in last transaction (kgs)	43.75	39.93
Trader has less than primary education (1/0)	0.16	0.37
Number of traders	166	166

Source: Authors calculation from study sample



Source: Authors calculation from study sample

Figure 1 Share of fresh vegetable samples with different microbial contamination

Table 2 Adoption rates of good hygiene and vegetable handline practices among traders

	Overall		**Tomatoes**		**Cucumbers**		**Carrots**	
	Share	SD	Share	SD	Share	SD	Share	SD
Changes water <=4 hours	0.52	0.50	0.75	0.44	0.35	0.48	0.34	0.48
Uses a plastic create to store/ move product(1/0)	0.12	0.32	0.24	0.43	0.01	0.11	0.04	0.19
Has good hygiene practices (1/0)	0.87	0.34	0.98	0.16	0.85	0.36	0.76	0.43
Separates vegetables for display (1/0)	0.80	0.40	0.89	0.31	0.74	0.44	0.76	0.43
Vegetables are sold on a raised platform(1/0)	0.83	0.38	0.77	0.42	0.94	0.23	0.84	0.37
Sorts vegetables after purchase (1/0)	0.95	0.23	1.00	0.00	0.91	0.29	0.90	0.30
Number of observations	166	166	166	166	166	166	166	166

Source: Authors calculation from study sample

Table 3 Determinants of the adoption of good hygiene practices

	(1) Change washing water well	(2) Sorting vegetables	(3) plastic crate	(4) Hygienic practices	(5) Separate vegetables	(6) Raised platform
Male	0.176**	0.081	-0.181***	-0.125***	-0.021	-0.037
Age	0.009***	-0.003	-0.001	0.002	0.001	0.002
Years of selling vegetables	0.001	0.006	0.001	0.001	-0.003	0.004
Qty of vegetables purchased in last transaction (kg)	0.009***	-0.005**	0.000	-0.011***	-0.006***	-0.005***
Squared quantity of vegetables purchased in last transaction (kg)	-0.000***	0.000	-0.000	0.000***	0.000***	0.000***
Has less than primary education (1/0)	-0.051	-0.042	0.030	-0.045	-0.054	0.032
Cost of water in the market (naira)	-0.001	-	-	-	-	-
Ogun Central	0.258***	-0.003	-0.162***	-0.002	0.153**	-0.113
Ogun East	0.104	0.129*	-0.088***	-0.037	0.173**	-0.199***
Ogun West (base)	-	-	-	-	-	-
Tomatoes	0.205***		0.124***	0.084*	0.182**	-0.042
Cucumber	-0.075	0.057	-0.085	0.039	-0.012	0.153**
Carrots (base)	-	-	-	-	-	-
Number of toilets in the market				0.115***		
Cost of using a toilet in the market				-0.032***		
	489	487	487	487	487	487

Source: Authors calculation from study sample using STATA 17. Explanatory variables included were selected based on the literature on their relevance to the associated practices.

Table 4 The association between good handling practices and microbial contamination in vegetable samples

Explanatory variables	*E. coli*	*Salmonella spp*	*Bacillus spp*
	APEs	APEs	APEs
Male vendor	0.084*	0.068	0.020
Age of the vendor	0.002	0.001	0.003**
Years selling vegetables	-0.002	0.001	-0.003*
May	-0.104***	-0.223***	-0.216***
October	-0.114***	-0.199***	-0.231***
March (base)	-	-	-
Changes water within 4 hours of first use	-0.101**	0.030	0.026
Sorts their vegetables after purchase	0.082	0.045	0.032
Quantity of vegetables purchased (kg)	0.001	-0.001	0.001
Squared quantity of vegetables purchased in last transaction (kg)	-0.000	-0.000	-0.000
Has less than primary education (1/0)	0.024	0.001	0.007
Uses plastic crates to store and move product	-0.006	0.002	-0.114*
Good hygiene practices	-0.101*	-0.008	-0.031
Separates vegetables on display	0.088*	0.021	0.051
Uses a raised platform	-0.067	-0.013	-0.024
Ogun Central	0.086*	0.020	-0.002
Ogun East	0.038	0.078*	-0.101*
Ogun West (base)	-	-	-
Tomato	-0.018	0.017	0.213***
Cucumber	-0.138***	0.029	0.309***
Carrots (base)	-	-	-
Number of observations	489	489	489
Number of traders			

Source: Authors calculation from study sample using STATA 1