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Assessment of Sanitation practices and the level of VOCs in cowhide in some Abattoirs in Delta state, Nigeria

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ABSTRACT

This study investigates the sanitation practices, and levels of volatile organic compounds (VOCs) in roasted cowhide in some abattoirs in relation to established health standards. A mixed-methods approach was employed, involving a demographic analysis of the workforce, surveys on sanitation practices, alongside laboratory testing for VOCs in roasted cowhide. A comprehensive demographic analysis revealed a predominance of older, married males, with 78% at Agbarho and 73% at Effurun Market being aged 46 years and above, and a high level of educational attainment, as 86% of respondents at Agbarho and 90% at Effurun had completed secondary school. Both abattoirs demonstrated strong adherence to cleaning and disinfection practices, with 100% compliance for daily cleaning and the use of VOC-free cleaning agents, although Effurun exhibited significant deficiencies in inventory management for cleaning supplies, achieving only 22% compliance in the schedule for replacing cleaning supplies. Notably, both locations displayed inadequate compliance in ventilation system maintenance and air quality control measures, with only 10% adherence to ventilation inspection and waste disposal evaluation reported at both abattoirs. The analysis of VOC levels in roasted cowhide from Effurun were alarmingly high, with benzene detected at 0.0237 mg/kg (more than twice the WHO limit of 0.01 mg/kg), while Agbarho showed no detectable levels of benzene. Additionally, compounds like 1,2-dibromo-3-chloropropane were found in concentrations of 0.1145 mg/kg in Effurun and 0.5509 mg/kg in Agbarho, both exceeding EPA limits. Overall, the findings emphasize the urgent need for enhanced regulatory compliance and improved sanitation practices in both abattoirs to safeguard public health.

1. INTRODUCTION

Cowhide, popularly referred to as "ponmo" in Nigeria, is a highly cherished delicacy and a significant source of livelihood in many communities. Beyond its cultural and economic importance, cowhide represents a critical aspect of the meat processing industry, serving as a valuable product in both rural and urban markets. However, its processing is often carried out using traditional and unconventional methods, such as singeing with open flames fueled by readily available materials like rubber tires, kerosene, and other combustible wastes. While these methods are economically viable and culturally ingrained, they raise serious

health and environmental concerns. Singeing with such materials leads to the release of harmful substances, particularly volatile organic compounds (VOCs), into the cowhide and the surrounding environment (Dada *et al*., 2020). VOCs, which are organic chemicals with high vapor pressure, are known to pose a range of health risks, including respiratory issues, neurological effects, and carcinogenic potential. These compounds also contribute to environmental problems, such as air and soil pollution, making their regulation a critical public health issue (Ali *et al.,* 2020).

The safety and quality of cowhide as a food product are further influenced by the sanitation practices adopted in abattoirs where these products are processed. In many Nigerian abattoirs, including those in Delta State, poor sanitary conditions have been documented, including the use of untreated water sources, unhygienic slaughtering procedures, inadequate waste disposal systems, and the absence of standard operating protocols for meat handling (Okojie and Isah, 2014). These conditions create a conducive environment for microbial growth and chemical contamination, which can further compromise the safety of cowhide. Moreover, the lack of effective regulatory oversight in abattoirs has contributed to the persistence of these substandard practices, exacerbating the risk of exposure to contaminated food products.

Despite the widespread consumption of cowhide across Nigeria, there is a notable paucity of research on the interplay between abattoir sanitation practices and the levels of VOCs in processed cowhide. This gap in knowledge is concerning, given the potential public health implications of consuming VOC-contaminated cowhide. Studies have shown that the consumption of improperly processed meat products can lead to chronic health issues, including organ toxicity and developmental problems, particularly in vulnerable populations such as children and pregnant women (Adeola *et al*., 2019). Furthermore, the environmental impact of VOC emissions from cowhide processing remains understudied, despite growing global concerns over air pollution and its effects on climate change.

Delta State, Nigeria, presents a unique case study for examining these issues due to its significant meat processing activities and high consumption rates of cowhide. The state's abattoirs serve a diverse population, making it imperative to understand the factors contributing to VOC contamination in cowhide and the broader implications for food safety and environmental health. Addressing these issues requires a multidisciplinary approach that integrates public health, environmental science, and policy development to ensure sustainable practices in the meat processing industry. This study aims to assess the sanitation practices in selected abattoirs in Delta State and evaluate the levels of VOCs in cowhide processed within these facilities. By investigating the relationship between hygiene standards and VOC contamination, this research seeks to fill critical knowledge gaps and provide evidence-based recommendations for improving meat processing practices. The findings are expected to inform policymakers, public health practitioners, and stakeholders in the meat industry, contributing to enhanced consumer safety, environmental protection, and sustainable development.

2. MATERIALS AND METHODS
2.1 Description of Study Area
The study was conducted at two abattoirs in Delta State, Nigeria: Effurun Market Abattoir in Uvwie Local Government Area (05°47'7.6538"N to 05°33'9.67752"N) and Agbarho Abattoir in Ughelli North Local

Government Area (05°50'56.18"N and 05°34'54.8"N). Both sites are strategically located near flowing rivers, which influence the dispersion and environmental impact of pollutants. Geologically, Delta State, part of the Niger Delta basin, consists of sedimentary formations, including sand, silt, clay, and peat, which facilitate the infiltration of pollutants into soil and groundwater (Olabode, 2022; Adekunle *et al.*, 2020). The vegetation of the study area includes Guinea savannah and freshwater swamp forests, which act as natural buffers by mitigating pollution and improving air quality. However, these ecosystems are at risk due to the proximity of the abattoirs and the potential release of pollutants, which can affect both flora and fauna (Iloeje, 2019; Nwokocha & Onyeagba, 2021).

2.2 Questionnaire Survey

To assess the current sanitation practices at the abattoirs, a structured questionnaire was utilized as the primary data collection tool. A total of 100 questionnaires were distributed, with 50 questionnaires administered at each abattoir. The questionnaire was designed to gather detailed information including information on abattoir sanitation practices, Ventilation and Air Quality in abattoirs environment, Monitoring and Testing Practices of air quality and employee sanitation Practices and Training in abattoirs in Agbarho and Effurun market abattoir. Each questionnaire comprised multiple-choice questions, Likert scale items, and open-ended questions to capture both quantitative and qualitative data. The questionnaire survey was conducted in person at both abattoir locations to ensure a high response rate and to clarify any questions the respondents might have had. The participants included abattoir workers, management staff, and other relevant stakeholders, ensuring a comprehensive assessment of the sanitary practices in place. The responses were collected over a specified period, with the data being subsequently coded and analyzed using statistical software. The analysis focused on identifying the level of compliance with sanitary standards, comparing the practices between the two abattoirs, and highlighting areas requiring improvement.

2.3 Collection and Laboratory analysis of VOCs in cowhide

Freshly processed, market-ready cowhide samples were collected directly from vendors at the selected abattoirs under controlled conditions, including minimal exposure to ambient air and avoidance of contact with potentially contaminating surfaces. The samples were promptly stored in sterile, airtight, and labeled containers under refrigerated conditions (at approximately 4°C) to preserve the integrity of volatile organic compounds (VOCs) prior to laboratory analysis.

For the determination of volatile organic compounds (VOCs), the Headspace Gas Chromatography (GC) method was utilized. A total of 2 g of each sample was weighed and transferred to a 10 mL headspace vial, which was capped tightly to prevent any loss of volatile compounds. The samples were then placed in the headspace carousel for analysis. The samples were analysed using an Agilent 8860 Gas Chromatograph equipped with a flame ionization detector (FID). The chromatographic setup included a DB-624 capillary column coated with 6% cyanopropyl/phenyl and 94% polydimethylsiloxane (30 m length x 0.53 mm diameter x 3 μm film thickness) (Agilent Technologies). The samples were injected in split mode (1:1) at an injection temperature of 250 °C, a pressure of 4.227 psi, and a total flow rate of 0.6 mL/min. The oven was initially programmed to maintain a

temperature of 35 °C for 5 minutes, followed by a ramp to 60 °C at a rate of 11 °C/min for 1 minute. The temperature was then increased to 220 °C at a rate of 220 °C/min. The FID temperature was maintained at 300 °C, with hydrogen and air flows set at 30 mL/min and 300 mL/min, respectively, while helium was used as the makeup gas at a flow rate of 18 mL/min.

Statistical analysis

All statistical analyses were conducted with Statistical Package for Social Scientists (SPSS) and Microsoft Excel computer software. The data collected from the sampling of the questionnaire were analyzed using the simple percentage method of data analysis. The simple percentage was used for easy understanding and clarity. Other data were presented as mean ± SE.

3. RESULT AND DISCUSSION
3.1 Results

The demographic and occupational analysis of Agbarho and Effurun Market abattoirs reveals notable trends. The workforce is largely composed of individuals aged 46 years and above, with 78% at Agbarho and 73% at Effurun Market, while younger age groups (18-25 and 26-45) are underrepresented, accounting for 6% and 16% at Agbarho, and 10% and 17% at Effurun Market, respectively (Figure 1). Gender distribution shows male dominance, with 86% of the workforce at Agbarho and 82% at Effurun Market being male, while female participation remains low (Figure 2). The workforce is predominantly married, with 96% at Agbarho and 92% at Effurun Market being married, leaving a small minority of single individuals (Figure 3). Educational attainment is high, as most respondents have completed secondary school, 86% at Agbarho and 90% at Effurun Market. A small percentage has university degrees (6% at Agbarho and 8% at Effurun Market), while 4% at Agbarho and 2% at Effurun Market have no formal education (Figure 4). Occupational data shows that business activities dominate, with 82% of respondents in Agbarho and 56% in Effurun Market engaged in business. Farming is more prominent in Effurun Market, where 40% of respondents are farmers, compared to 16% at Agbarho (Figure5).
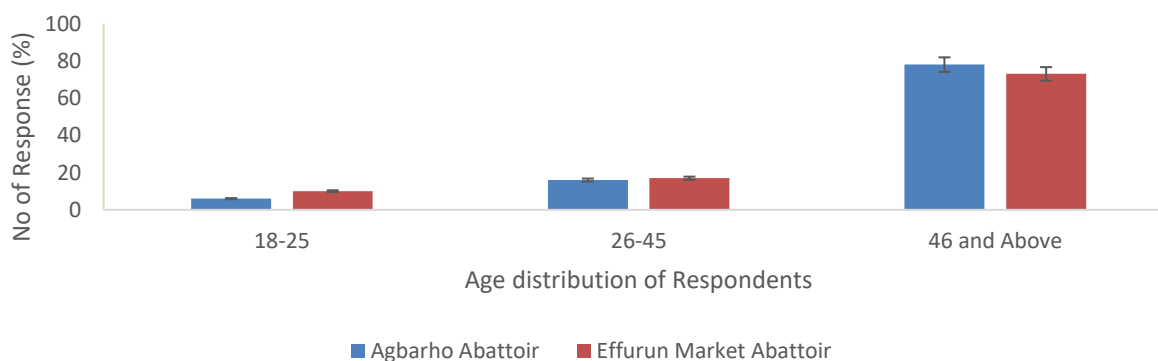
Figure 1: Age of respondents during the investigation on the sanitation practices in abattoirs
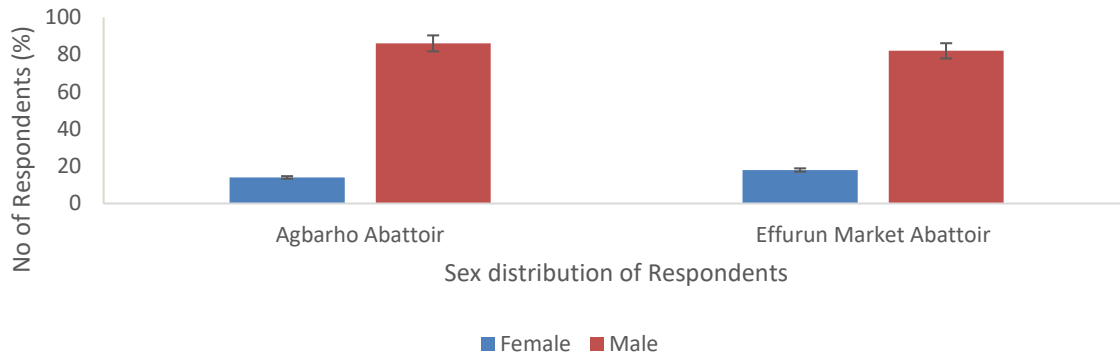
Figure 2: Gender of respondents during the investigation on the sanitation practices in abattoirs
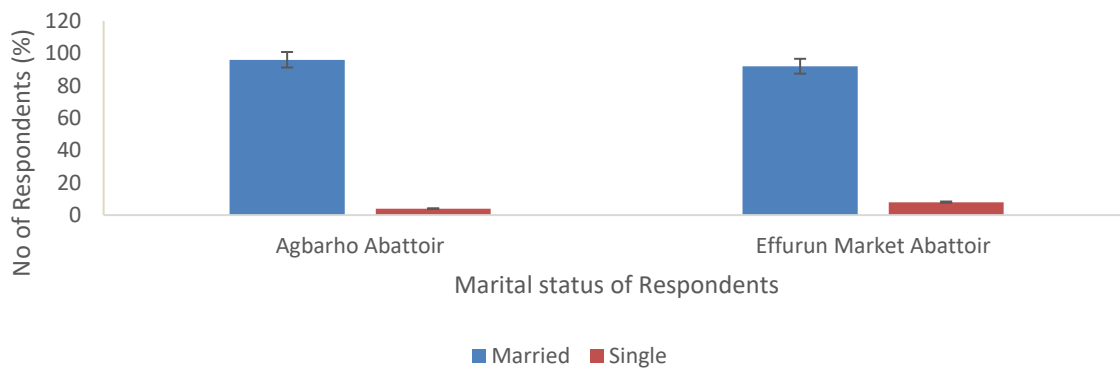
Figure 3: Marital status of respondents during the investigation on the sanitation practices in abattoirs
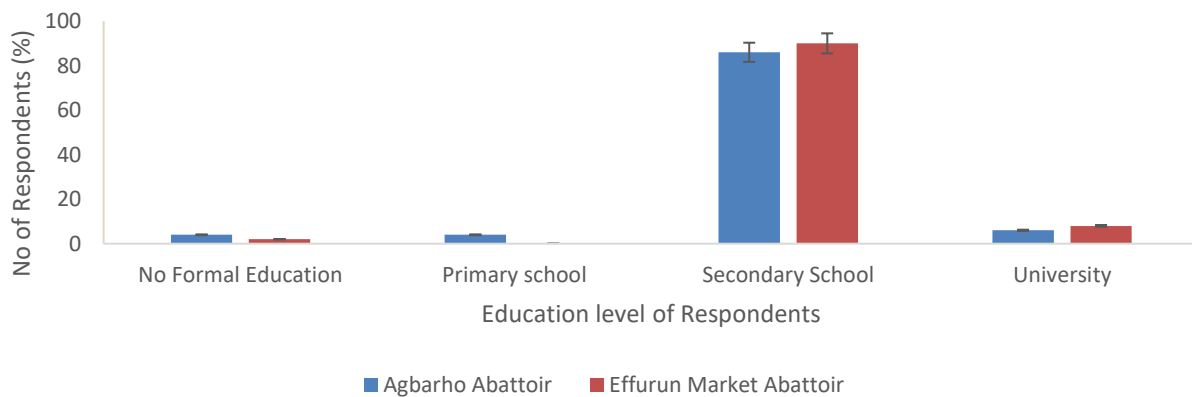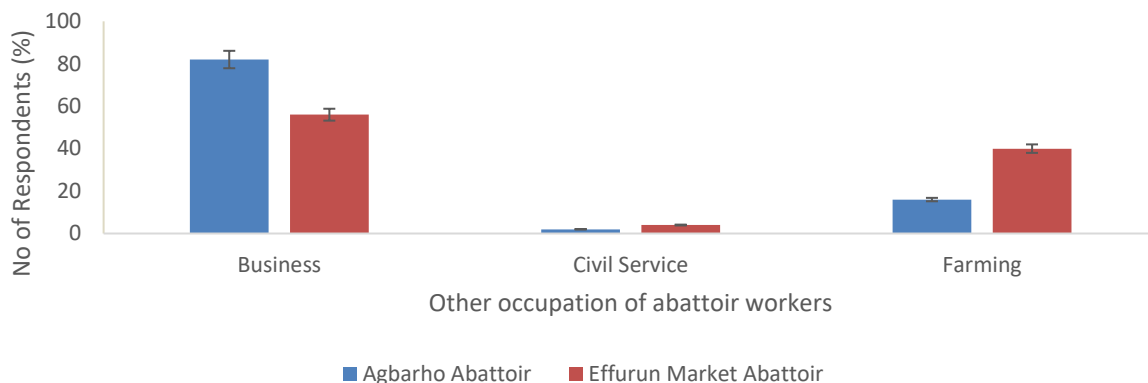

Figure 4: Education level of respondents during the investigation on the sanitation practices in abattoirs

Figure 5: Occupation of respondents during the investigation on the sanitation practices in abattoirs

The table1 presents the percentage of positive responses from Agbarho and Effurun Market abattoirs regarding cleaning, disinfection, and waste management practices. Both abattoirs demonstrate strong adherence to key hygiene practices, such as daily cleaning (100% for both abattoirs), the use of VOC-free cleaning agents (100% for both abattoirs), and the presence of designated waste disposal areas (98% for Agbarho and 100% for Effurun). However, the notable difference lies in the documented schedule for replacing cleaning supplies, with Agbarho achieving 100% compliance compared to only 22% in Effurun Market abattoir. This discrepancy suggests that Effurun Market may need to improve its inventory management and operational procedures to ensure consistent sanitation efficacy over time.

Table 1: Responses of abattoir workers on Sanitation Practices in the abattoirs

S/N	Questions	Agbarho (%)	Effurun Market (%)
1	Are cleaning and disinfection procedures conducted daily?	100.00	100.00
2	Are cleaning agents used in the abattoir VOC-free or low-VOC?	100.00	100.00
3	Is there a designated area specifically for waste disposal?	98.00	100.00
4	Are disinfectants used in the abattoir approved for use in environments where food is processed?	100.00	98.00
5	Is there a documented schedule for replacing or replenishing cleaning supplies to maintain efficacy?	100.00	22.00

NB: Results above shows only affirmative response to the questionnaire

This table 2 reflects the percentage of positive responses concerning the inspection, maintenance, and management of ventilation systems and air quality control measures, particularly in relation to volatile organic compounds (VOCs), at the Agbarho and Effurun Market abattoirs. The data indicates that both abattoirs exhibit significantly low levels of compliance with ventilation system maintenance, air quality monitoring, and VOC control measures. Agbarho abattoir shows slightly higher, though still inadequate, adherence in areas such as ventilation inspection (10%) and waste

disposal evaluation (10%) compared to Effurun Market abattoir. The minimal efforts (4%) reported by both abattoirs in planning to upgrade ventilation systems highlight the need for increased focus on enhancing indoor air quality control mechanisms.

Table 2: Responses of abattoir workers on Ventilation and Air Quality in the abattoirs

S/N	Questions	Agbarho (%)	Effurun Market (%)
1	Are ventilation systems regularly inspected and maintained?	10.00	0.00
2	Is air quality (including VOC levels) monitored regularly within the abattoir?	8.00	2.00
3	Are there measures to control VOC emissions from sources other than cleaning agents (e.g., equipment)?	2.00	2.00
4	Are waste disposal methods evaluated periodically to ensure they minimize VOC emissions?	10.00	2.00
5	Are there plans or initiatives in place to upgrade ventilation systems to reduce VOC concentrations?	4.00	4.00

NB: Results above shows only affirmative response to the questionnaire

Table 3 presents positive response rates regarding testing, sanitation, and reporting procedures for volatile organic compounds (VOCs) in meat products at the Agbarho and Effurun Market abattoirs. Agbarho demonstrates higher adherence to sanitation inspections (92%) and procedures for VOC spill cleanup (20%), but it lags behind in establishing formal systems for reporting VOC concerns (28%). Conversely, Effurun Market, despite lower compliance in some areas, shows a stronger commitment to addressing VOC-related issues, with 56% of respondents indicating the presence of reporting systems. Notably, both abattoirs exhibit minimal focus on testing meat products for VOC levels, with only 2% in Agbarho and 0% in Effurun Market, underscoring a critical gap in consumer safety measures. Furthermore, the lack of complaints regarding odours does not necessarily indicate the absence of VOC contamination but may reflect inadequate detection and reporting mechanisms.

Table 3: Responses of abattoir workers on monitoring and testing practices in the abattoirs

S/N	Questions	Agbarho (%)	Effurun Market (%)
1	Are meat products tested for VOC levels before packaging and distribution?	2.00	0.00
2	Have there been any reports or complaints regarding noticeable odours in meat products?	2.00	0.00
3	Are there procedures in place for immediate cleanup of spills involving VOC-containing substances?	20.00	14.00
4	Are there inspections or audits conducted to ensure compliance with sanitation and VOC emission standards?	92.00	80.00
5	Is there a system in place for reporting and addressing concerns related to VOC emissions?	28.00	56.00

NB: Results above shows only affirmative response to the questionnaire

Table 4 compares worker engagement in sanitation and VOC emission control at the Agbarho and Effurun Market abattoirs. In Agbarho, 88% of workers reported receiving training on sanitation and VOC procedures, slightly lower than Effurun Market's 94%. PPE compliance is high in both locations, with 98% in Agbarho and 100% in Effurun Market confirming its use. Regular communication on VOC control is held for 92% of Agbarho workers and 100% in Effurun Market, indicating more consistent communication in the latter. Additionally, 96% of Agbarho workers felt encouraged to report issues, compared to 100% in Effurun Market, suggesting slight room for improvement in Agbarho's reporting culture.

Table 4: Responses of abattoir workers on employee practices and training in the abattoirs

S/N	Questions	Agbarho (%)	Effurun Market (%)
1	Are workers trained on proper sanitation and VOC emission control procedures?	88.00	94.00
2	Is personal protective equipment (PPE) required during handling of cleaning agents and waste?	98.00	100.00
3	Are there regular meetings or communications with staff regarding VOC emission control measures?	92.00	100.00
4	Are employees encouraged to report any issues related to sanitation and VOC emissions?	96.00	100.00

NB: Results above shows only affirmative response to the questionnaire

Table 5 highlights key differences in VOC emission control and regulatory compliance between the Agbarho and Effurun Market abattoirs. In Effurun Market, 100% of workers confirmed compliance with local regulations, while only 82% did in Agbarho. Record-keeping is much lower in Agbarho (12%) compared to Effurun Market (56%). Additionally, only 4% of workers in Agbarho and 24% in Effurun Market reported having a staff member responsible for VOC control. Both abattoirs lack formal incident response procedures, with only 10% of Agbarho workers and 4% in Effurun Market confirming their existence. However, both locations show strong commitment to staying updated on regulations (98% in both) and report high stakeholder involvement in decision-making (100% in Effurun Market and 98% in Agbarho).

Table 6 compares VOC levels in roasted cowhide from Agbarho and Effurun abattoirs, with an emphasis on how these levels align with WHO and EPA standards. The analysis reveals that cowhide from Effurun abattoir generally exhibits significantly higher concentrations of VOCs, many of which exceed safety thresholds, highlighting substantial environmental and health risks. Benzene, for example, was detected in Effurun's cowhide at 0.0237 mg/kg, a level more than twice the WHO limit of 0.01 mg/kg and nearly five times the EPA limit of 0.005 mg/kg. In contrast, no benzene was found in cowhide from Agbarho abattoir, illustrating a stark difference in contamination levels.Further, trichloroethene in Effurun's cowhide was measured at 0.0118 mg/kg, which is below the WHO limit but exceeds the EPA limit, suggesting potential environmental concerns. Similarly, cis-1,3-dichloropropene levels were alarmingly high

in Effurun's cowhide, far surpassing EPA guidelines, whereas it was undetected in Agbarho's cowhide.

Table 5: Responses of abattoir workers on regulatory compliance of Sanitation Practices in the abattoirs

S/N	Questions	Agbarho (%)	Effurun Market (%)
1	Does the abattoir comply with local regulations regarding VOC emissions and sanitation practices?	82.00	100.00
2	Are there records kept of VOC emissions and sanitation practices for regulatory purposes?	12.00	56.00
3	Is there a designated staff member responsible for overseeing VOC emission control measures?	4.00	24.00
4	Are there documented procedures for responding to VOC emission incidents?	10.00	4.00
5	Are there on-going efforts to stay updated with new regulations and best practices for VOC emissions?	98.00	98.00
6	Are stakeholders, including management and workers, involved in decision-making processes regarding VOC emission control measures?	98.00	100

NB: Results above shows only affirmative response to the questionnaire

On a more positive note, toluene concentrations were found to be within safe limits at both abattoirs, with Effurun recording 0.0077 mg/kg and Agbarho 0.0204 mg/kg, both well below the WHO and EPA limits. However, the analysis also indicates that both abattoirs pose risks, as compounds like isopropylbenzene and 1,2-dibromo-3-chloropropane were detected at levels exceeding EPA limits in cowhide from both locations. Specifically, 1,2-dibromo-3-chloropropane was found in concentrations far above the EPA limit, with Effurun's sample at 0.1145 mg/kg and Agbarho's at 0.5509 mg/kg, underscoring significant potential health hazards. Overall, the data suggest that roasted cowhide from Effurun abattoir presents a higher risk of VOC contamination compared to Agbarho, but both locations show concerning levels of certain toxic compounds.

3.2 Discussion

The demographic analysis of abattoir workers at Agbarho and Effurun Market provides insight into the composition of their workforce. Notably, both locations are dominated by individuals aged 46 years and above, with 78% and 73% of the respondents at Agbarho and Effurun Market, respectively, belonging to this age group. This pattern reflects a predominance of older workers in the industry, with fewer younger participants aged 18-25 (6% at Agbarho, 10% at Effurun) and 26-45 (16% at Agbarho, 17% at Effurun). These trends could indicate a generational shift, where younger individuals are not engaging in abattoir work, possibly due to societal changes, education, or alternate career preferences. Comparatively, the dominance of older workers aligns with findings from studies in other industries, where older age groups tend to occupy more

physically demanding roles that younger individuals avoid (Adeoye *et al*., 2019).

Table 6: Volatile organic compounds (VOCs) presents in roasted cow - hide.

Volatile Organic Compounds	Agbarho	Effurun	WHO limit	EPA limit
Benzene [mg/kg]	N.D.	0.0237±0.012	0.01	0.005
1,2-Dichloroethane [mg/kg]	N.D.	0.0016±0.001	0.03	0.005
Trichloroethene [mg/kg]	N.D.	0.0118±0.007	0.02	0.005
1,2-Dichloropropane [mg/kg]	N.D.	N.D.	-	0.005
Dibromomethane [mg/kg]	N.D.	N.D.	-	-
Bromochloromethane [mg/kg]	N.D.	0.631±0.017	-	-
cis-1,3-Dichloropropene [mg/kg]	N.D.	0.3744±0.087	-	0.001
Toluene [mg/kg]	0.0204±0.006	0.0077±0.002	0.7	1.0
Trans-1,3-Dichloropropane [mg/kg]	N.D.	N.D.	-	-
1,1,3-Trichloroethane [mg/kg]	0.0712±0.022	N.D.	-	-
Tetrachloroethene [mg/kg]	0.0123±0.005	0.0086±0.002	0.04	0.005
Dibromochloromethane [mg/kg]	0.0517±0.012	N.D.	-	0.06
Bromochloromethane [mg/kg]	0.0344±0.011	0.0352±0.016		
Chlorobenzene [mg/kg]	N.D.	N.D.	-	0.1
m-Xylene+p-Xylene [mg/kg]	0.0023±0.001	0.0053±0.002	0.5	10
Ethylbenzene [mg/kg]	0.0314±0.008	0.0051±0.001	-	0.7
o-Xylene [mg/kg]	0.0107±0.005	0.0052±0.001	0.5	10
Bromoform [mg/kg]	N.D.	N.D.	-	0.08
Isopropylbenzene [mg/kg]	0.0064±0.001	0.0148±0.004	-	0.001
Bromobenzene [mg/kg]	0.0226±0.013	N.D.	-	-
1,1,2,2-Tetrachloroethane+1,2,3-Trichloropropane [mg/kg]	0.0097±0.001	N.D.	-	0.031
n-Propylbenzene [mg/kg]	0.0202±0.007	0.0135±0.001	-	-
2-Chlorotoluene [mg/kg]	0.0071±0.001	0.0051±0.001	-	-
1,3-Dichlorobenzene [mg/kg]	0.0085±0.002	N.D.	-	-
4-Chlorotoluene [mg/kg]	N.D.	N.D.	-	-
1,4-Dichlorobenzene [mg/kg]	0.0022±0.001	N.D.	0.3	0.075
p-isopropyltoluene [mg/kg]	0.0401±0.014	0.0135±0.005	-	-
1,2-Dichlorobenzene [mg/kg]	0.1056±0.061	0.0127±0.004	-	0.6
Butylbenzene [mg/kg]	0.0118±0.004	0.0034±0.001		
1,2-Dibromo-3-chloropropane [mg/kg]	0.5509±0.025	0.1145±0.041	-	0.0002
1,2,4-Trichlorobenzene [mg/kg]	0.0269±0.011	0.0459±0.035	-	0.07
Hexachlorobutadiene [mg/kg]	0.0969±0.014	0.0424±0.021	-	-
Naphthalene [mg/kg]	0.0018±0.001	N.D.	0.02	-
1,2,3-Trichlorobenzene [mg/kg]	N.D.	0.0229±0.014	-	0.005

The male dominance observed, with 86% at Agbarho and 82% at Effurun, reflects broader cultural norms within Nigeria, where men predominantly engage in labour-intensive

occupations, while women are less represented in such sectors (Omoruyi *et al.*, 2021). Gender imbalances in the workforce can be traced to traditional views of abattoir work as physically demanding and unsuited for women. The high percentage of married workers (96% in Agbarho, 92% in Effurun) may indicate that more established family-oriented individuals take on these roles, possibly because of the economic stability abattoir work provides, despite its challenges. Both abattoirs exhibit strong adherence to key sanitation practices. The data shows that 100% of respondents at both sites reported daily cleaning and the use of VOC-free cleaning agents. However, discrepancies emerge in the regular replacement of cleaning supplies, where Effurun Market (22%) lags far behind Agbarho (100%). This suggests potential issues in supply chain management at Effurun, which could undermine long-term sanitation effectiveness. Proper cleaning and waste management practices are essential for ensuring food safety and protecting public health (Adeoye *et al.*, 2019). The high compliance with daily cleaning is consistent with findings from abattoir operations worldwide, where sanitation is a top priority to prevent contamination (Omoruyi *et al.*, 2021). However, the gap in cleaning supply management in Effurun may expose workers and consumers to hygiene risks if not addressed.

The ventilation and air quality data reveal that both abattoirs are significantly non-compliant with best practices for maintaining air quality and ventilation systems. For instance, only 10% of Agbarho and 4% of Effurun respondents reported any maintenance of ventilation systems. This neglect poses serious risks, as abattoirs are prone to accumulating volatile organic compounds (VOCs) that can affect both workers and the surrounding environment.

Studies highlight that inadequate ventilation in abattoirs can contribute to respiratory issues among workers and increase the risk of meat contamination (Ogbonna & Ahmed, 2020). While both locations show some degree of ventilation system planning (Agbarho 10%, Effurun 4%), these figures are far below the recommended standards for indoor air quality in such facilities. Improving ventilation and VOC control should be a priority for both abattoirs to safeguard worker health and ensure a safer working environment.

The results for monitoring and testing VOCs in meat products show deficiencies in both abattoirs. Agbarho outperforms Effurun in sanitation inspections (92% vs. 56%) and VOC spill clean-up (20% vs. 12%). However, neither abattoir has robust systems for testing meat products for VOC contamination, with Agbarho at 2% and Effurun at 0%. This is concerning, as VOCs can adversely affect meat quality and consumer health if left unmonitored. Studies by Okechukwu *et al.* (2022) emphasize the importance of regular VOC testing in food products to ensure compliance with health standards. The lack of formal reporting systems for VOC concerns (28% in Agbarho, 56% in Effurun) indicates a critical gap in safety protocols, which should be addressed to enhance food safety measures.

The level of worker engagement in training and sanitation practices is commendable in both abattoirs, with 88% of Agbarho and 94% of Effurun workers reporting sanitation and VOC training. The use of personal protective equipment (PPE) is also high, with nearly universal compliance at both locations. These results align with the global trend towards improving workplace safety through regular training and the use of protective gear (Adeoye *et al.*, 2019). However, Agbarho lags slightly behind Effurun in communication regarding VOC

control (92% vs. 100%) and in workers' encouragement to report issues (96% vs. 100%). Encouraging open communication and reporting is essential for maintaining a culture of safety and continuous improvement in sanitation practices.

Effurun Market abattoir exhibits higher compliance with local regulations and better record-keeping than Agbarho, with 100% of Effurun workers confirming compliance, compared to 82% at Agbarho. Record-keeping practices are particularly concerning at Agbarho, where only 12% of respondents reported keeping records, compared to 56% at Effurun. Proper record-keeping is critical for tracking sanitation practices, ensuring accountability, and demonstrating compliance with regulatory standards (Ogbonna & Ahmed, 2020). Furthermore, the lack of designated staff responsible for VOC control (Agbarho 4%, Effurun 24%) reveals a gap in abattoir management practices. Addressing these issues will enhance regulatory compliance and ensure better oversight of hygiene and VOC emissions. Both abattoirs should prioritize formalizing incident response procedures, which are currently inadequate, to quickly and effectively address any sanitation or VOC-related concerns that may arise.

Volatile organic compounds (VOCs) in food products, particularly those exposed to burning or industrial processes, pose significant environmental and health risks. Among these, benzene is a well-known carcinogen that has been frequently detected in processed foods and animal products, raising concerns about their safety for consumption (Anderson *et al*., 2018). The high levels of benzene in Effurun's cowhide mirror findings from other studies showing that open-air roasting with improper fuel sources leads to significant VOC contamination (Olaniyi *et al*., 2020). The presence of trichloroethene and cis-1,3-dichloropropene in the samples further supports previous research indicating that these compounds, often used in industrial solvents and pesticides, can migrate into animal products during processing (Huang & Lei, 2019). The lack of these compounds in Agbarho's samples suggests that environmental or procedural differences between abattoirs play a critical role in determining contamination levels. However, this study extends the current knowledge base by emphasizing the presence of isopropylbenzene and 1,2-dibromo-3-chloropropane, two VOCs less commonly discussed in relation to food safety. Both compounds are recognized environmental pollutants, but their detection at dangerous levels in edible cowhide highlights the need for stricter control measures and further research into their pathways of contamination.

The results of this study largely support previous research that links improper roasting methods and poor environmental controls in abattoirs to high VOC contamination (Anderson *et al*., 2018; Olaniyi *et al*., 2020). However, the findings contradict studies that suggest VOC contamination is relatively uniform across similar environments (Huang & Lei, 2019). The stark contrast in benzene and cis-1,3-dichloropropene levels between Agbarho and Effurun abattoirs underscores the importance of localized factors such as roasting technique, fuel quality, and abattoir hygiene. Moreover, this study extends the body of research by revealing elevated levels of 1,2-dibromo-3-chloropropane, a carcinogenic compound not commonly associated with food products. The detection of this compound at concentrations far exceeding EPA limits points to the need for further investigation into chemical use and environmental contamination in abattoirs, as well as its potential impacts on food safety.

4. CONCLUSION

The findings of this study indicate that both Agbarho and Effurun Market abattoirs face significant challenges regarding sanitation practices, air quality management, and the presence of harmful VOCs in roasted cowhide. Despite high compliance rates in certain cleaning and waste management practices, critical gaps exist in areas such as inventory management for cleaning supplies, ventilation system maintenance, and VOC testing. The detection of VOC levels exceeding health standards, particularly in Effurun abattoir, underscores the urgent need for regulatory compliance and intervention strategies to mitigate health risks. Addressing these issues is essential not only for the protection of workers and consumers but also for the sustainability of the meat processing industry in the region.

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