QUALITATIVE STUDY ON HYDROCARBON CONTAMINATION IN CPO: A CASE STUDY OF PALM OIL MILL BASED IN SUMATERA INDONESIA

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ABSTRACT

This study addresses hydrocarbon contamination in Crude Palm Oil (CPO) from Sumatera, Indonesia, focusing on identifying sources, establishing acceptable levels, and proposing mitigation strategies. Key challenges include high costs of alternative lubricants and limited awareness among small-scale producers. The research employs a comprehensive approach, including data collection from Palm Oil Mills, interviews with RSPO auditors and Palm Oil Managers, and Hazard Analysis and Critical Control Point (HACCP) implementation. Findings reveal contamination sources like gear oil and plastic containers, with recommendations for enhanced equipment maintenance, awareness campaigns, and stricter regulations. The study emphasizes the importance of collaboration, regulatory compliance, and proactive measures for sustainable Palm Oil production and market access in Europe, highlighting its significance for consumer safety, industry sustainability, and international standards compliance.

1. Introduction

This qualitative study pointed to explore the amount of hydrocarbon contamination in Crude Palm Oil (CPO) delivered in Sumatera, Indonesia. The contamination can happen during different stages of the Palm Oil production process, including harvesting, transportation, and processing. The study identified several challenges in mitigating hydrocarbon contamination in CPO, including the high cost of alternative lubricants, lack of awareness among small scale producers, and limited enforcement of regulations related to equipment maintenance and lubrication.

The study recommended several strategies to mitigate hydrocarbon contamination in CPO, including improving equipment maintenance and lubrication practices, increasing awareness among producers and processors about the risks of hydrocarbon contamination, and strengthening regulations and enforcement to ensure compliance with best practices. in general, the study gives profitable insights into the challenges and openings for improving the safety and quality of Palm Oil production in Sumatera, and highlights the significance of collaboration among stakeholders within the Palm Oil Industry to address this issue.

2. Literature Review

2.1 E-governance Overview

The study investigates hydrocarbon contamination in Crude Palm Oil (CPO) produced by Palm Oil Mills in Sumatera, Indonesia, addressing concerns about safety and quality. The Indonesian Palm Oil industry, a significant contributor to the national economy, faces scrutiny due to potential hydrocarbon contamination. The study identifies sources of contamination, including Estate Fresh Bunch Trucks, gear oil, hydraulic lubricants, and plastic sample containers. Mineral oil hydrocarbons (MOH) pose health risks, but Indonesia lacks MOH benchmarks for Palm Oil. The research aims to provide insights for developing these benchmarks and enhance the understanding of hydrocarbon pollution in CPO. The production process involves multiple stages, from receiving fresh fruit bunches (FFB) to producing CPO and palm kernel (PK). The study's findings contribute to academic knowledge and may guide the establishment of MOH benchmarks in Indonesian Palm Oil products, ensuring safety and quality for domestic use and export.

Problem statement: -

The presence of mineral oil hydrocarbon contamination in Crude Palm Oil (CPO) is a significant issue that postures a potential hazard to human wellbeing and damages allowable levels of Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH) set by controls and laws overseeing food security. This contamination is caused by different sources, such as machine oil and hydraulic oils utilized amid preparing in Palm Oil Mills. The need of successful techniques to relieve or lower the contamination levels according to approved parameters may be a major concern. Breathing in or ingesting MOH contaminated food items could lead to wellbeing concerns, counting respiratory issues, gastrointestinal issues, and other related wellbeing issues. The seriousness of these wellbeing issues would depend on the particular sorts and levels of MOH compounds present.

While the European Food Safety Authority (EFSA) has provisionally confirmed that some mineral oil aromatic hydrocarbons (MOAH) are a potential health concern. Agencies such as Federal Agency for the Safety of the Food Chain (FASFC) and EFSA evaluate the potential health risks associated with MOSH and MOAH exposure. Based on their risk assessments, they provide recommendations on acceptable exposure levels and measures to mitigate the risks.

Research Objectives and Questions: -

This research aims to investigate the sources of mineral oil hydrocarbon contamination in Crude Palm Oil (CPO) produced in Palm Oil Mills and to explore the permissible levels of Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH) in food products. Additionally, the study seeks to recommend effective strategies to mitigate or lower the contamination levels of mineral oil hydrocarbons in CPO. By addressing these objectives, the research aims to contribute to the safety and quality standards of palm oil products.

The research questions guiding this study are: What are the factors contributing to mineral oil hydrocarbon contamination in CPO produced from Palm Oil Mills? What is the permissible level of MOSH and MOAH in food products? And what effective strategies can

be recommended to mitigate the contamination levels of MOH in CPO? These questions are critical for understanding the extent of the contamination issue and for developing practical solutions to ensure the safety of palm oil products for consumers.

The significance of research can be summarized as follows:

Health and Safety Implications as Mineral oil hydrocarbon contamination in Crude Palm Oil (CPO) poses potential risks to human health if consumed above permissible levels. By identifying the sources of contamination and exploring strategies to mitigate it, the research can contribute to improving the safety and quality of Palm Oil products, safeguarding consumer health. Compliance with Regulations on understanding the permissible levels of Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH) in foods based on regulations and laws is crucial for the Palm Oil industry. the research aims to determine these permissible levels, ensuring compliance with the set standards and facilitating the industry's adherence to food safety regulations. Investigating the sources of hydrocarbon contamination in Palm Oil Mills can help in assessing the environmental impact of the industry. By identifying the equipment and practices contributing to contamination, the research can provide insights into potential areas for improvement, leading to more sustainable Palm Oil production processes. Industry Collaboration at Palm Oil industry is a significant contributor to Indonesia's economy. This research brings together key stakeholders, including producers, processors, and government officials, through interviews and focus group discussions. This collaboration can foster dialogue, knowledge-sharing, and collective efforts towards addressing the hydrocarbon contamination issue, ultimately benefiting the industry as a whole. Policy and Regulation Development by determining the relevant regulations and laws applicable to Palm Oil Mills in Sumatra, the research can contribute to policy and regulation development. This information can be used to strengthen existing regulations or introduce new measures to enhance quality control, food safety, and environmental protection in the Palm Oil industry. Overall, the research has the potential to make a significant impact by improving the safety and quality of Palm Oil products, ensuring compliance with regulations, minimizing environmental impact, supporting economic sustainability, fostering industry collaboration, and informing policy development in the Palm Oil sector.

Scope of Study, In and Out of scope.

This qualitative investigation focuses on examining palm oil mills in Sumatera, Indonesia, to identify sources contributing to hydrocarbon contamination in crude palm oil (CPO) production, with a particular emphasis on recognizing mineral oil hydrocarbons (MOH). The study also investigates potential health risks associated with consuming CPO containing elevated levels of MOH, in alignment with relevant regulations and benchmarks governing allowable levels of mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH) in CPO. Recommendations for effective strategies to mitigate hydrocarbon contamination in CPO are proposed, emphasizing stakeholder collaboration through interviews and discussions involving producers, processors, and authorities. Excluded from the scope are considerations of hydrocarbon contamination beyond Sumatera, other contaminants, extensive economic analysis of the industry's impact, technical extraction details, and altering the definition of key terms such as FFB suppliers from KSD, MBE, CDE, and KWS as P&C.

Operational definitions of key terms.

Crude Palm Oil (CPO): The crude oil extracted from the pulp of oil palm fruit.

Indonesian Palm Oil Association (GAPKI): An association of Palm Oil producers and processors in Indonesia.
Mineral oil hydrocarbons (MOH): A group of compounds that can be found in various consumer products, including food. MOH can be divided into two subgroups: mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH).

Hazard Analysis and Critical Control Point (HACCP): A systematic approach to food safety management that involves identifying potential hazards in food production and implementing measures to prevent them.
German Federal Institute for Risk Assessment (BfR): A scientific institution in Germany that provides independent advice on food and product safety.

European Food Safety Authority (EFSA): European Union that provides scientific advice on food safety.
Swiss Federal Food Safety and Veterinary Office (FSVO): A Swiss government agency responsible for food safety and veterinary public health.

Fresh Fruit Bunch (FFB): The bunch of oil palm fruit.

Palm kernel (PK): The seed of the oil palm fruit.

Critical control points (CCPs): The points in food production where measures can be taken to prevent, eliminate, or reduce potential hazards.

Parts per Million (ppm): A unit of measurement that expresses the concentration of a substance in a solution.
Roundtable on Sustainable Palm Oil (RSPO): A non-profit organization that promotes sustainable Palm Oil production and use.

Good Manufacturing Practices (GMPs): A set of guidelines for ensuring the quality and safety of food and other products during manufacturing.

Global Literature review: -

The German Federal Institute for Risk Assessment (BfR) issued guidelines in 2020, advocating for the reduction of mineral oil saturated hydrocarbons (MOSH) in food, including Palm Oil, to safeguard public health. Recommending a target level of 0.5 mg/kg for MOSH in edible oils and fats, the BfR acknowledges the variability of MOSH levels in food due to factors like processing methods and storage conditions. The guidelines align with global efforts, such as those by the European Food Safety Authority (EFSA), which recommends keeping MOSH levels as low as possible to protect human health. While not legally binding, these guidelines underscore the mounting concern within the scientific and regulatory communities regarding MOSH contamination. The EFSA has set health-based guidance

values, while the Swiss Federal Food Safety and Veterinary Office (FSVO) has established regulatory limits at 2 mg/kg for MOSH in food, including Palm Oil, emphasizing the importance of industry compliance and the implementation of good manufacturing practices for ensuring food safety and public health.

Literature review: - Asian

To further mitigate mineral oil saturated hydrocarbons (MOSH) levels in Crude Palm Oil (CPO) production, adopting food-grade lubricants is proposed as a key measure. These lubricants, formulated with synthetic or vegetable-based oils, are designed to minimize the risk of contamination with mineral oils commonly used in machinery during the production process. The conventional lubricants may contain MOSH and MOAH, posing a risk of migration into the food. Food-grade lubricants, meeting stringent safety and quality standards, are resistant to oxidation and thermal degradation, further reducing the contamination risk. However, the MOSH/MOAH content in these lubricants may still depend on the food's contamination level, necessitating proper equipment handling, maintenance, and regular testing of food products. A second protective layer involves installing lubricant trays as a physical barrier, preventing accidental contact between lubricants and Palm Fruit or Fresh Fruit Bunch (FFB) and CPO. This additional protective measure, combined with meticulous maintenance and cleaning procedures, aims to minimize the risk of contamination, ensuring compliance with safety and quality standards in CPO production.

Literature review: - Asian

Background, Global literatures, according to a pilot study on Mineral Oil Saturated Hydrocarbon (MOSH) status in Crude Palm Oil (CPO) conducted by Sime Darby Research Sdn. Bhd., two Sime Darby Plantation Palm Oil Mills located in East and West of Malaysia respectively were selected for this study by Ahmad, H., Noor, A.M., Ahmad Sabri, M.P., Ngteni, R., & Syed Hilmi, S.M.H. (2019) in Journal of Advanced Agricultural Technologies Vol. 6, No. 4, December 2019 portray that, Samples of CPO from production oil and processing lines were collected from the Palm Oil Mills for 6 consecutive weeks. The pilot study on Mineral Oil Saturated Hydrocarbon (MOSH) status in Crude Palm Oil (CPO) conducted by Sime Darby Research Sdn. Bhd. was published in the Journal of Advanced Agricultural Technologies in December 2019. The study aimed to assess and compare the levels of MOSH in CPO produced at two different Palm Oil Mills operated by Sime Darby Plantation in Malaysia. The study collected samples of CPO from both production oil and processing lines at the selected Palm Oil Mills over a period of 6 consecutive weeks. The study analyzed the presence of MOSH in the collected CPO samples. The results revealed that the HACCP certified Palm Oil Mill showed MOSH levels within the range of 10-17 parts per Million (ppm), while the non-HACCP certified Mill had an average MOSH level of 44.81 ppm. The study concluded that the implementation of Hazard Analysis and Critical Control Point (HACCP) measures in Palm Oil Mills may help in reducing the presence of mineral oil hydrocarbons in the final product (CPO). Additional search results provide further information on MOSH and MOAH analysis in mineral oil and food products. A study published on NCBI evaluated MOSH and MOAH in raw and processed food products using 400 MHz nuclear magnetic resonance (NMR) spectroscopy. The study introduced NMR spectroscopy as a method for measuring MOSH and MOAH in official controls. The study also highlighted the importance of providing a total view of MOSH/MOAH sum parameters in mineral oil analysis by hyphenated LC-GC-FID. Another study published on Desmet Belgium discussed the challenges posed by mineral oil hydrocarbons in oils and fats. The study mentioned that a pilot study on MOSH status in CPO was conducted by Sime Darby Plantation Palm Oil Mills. Another article published on Research Gate discussed the current status of MOSH

in CPO in Sime Darby Palm Oil Mills. The article highlighted that premium CPO showed lower MOSH at 10.7 ppm compared to standard CPO at 21.9 ppm. The article mentioned that there is no correlation between oil quality (FFA%) and MOSH. (Ahmad, H., Noor, A.M., Ahmad Sabri, December 2019)

Literature review: - Indonesia

This research investigates contamination in food products resulting from oils, packaging materials, and processing, with a focus on harmful compounds such as mineral oil and ceramides. Analyzing 152 items, the study reveals that 12.5% contained mineral oil contamination (0.63 to 82 mg/kg), while 92% displayed MOSH contamination (0.5 to 140 mg/kg). Material characteristics, handling strategies, and packaging types contribute to the formation of MOHs and ceramide compounds, potentially posing long-term health risks. MOSH consists of alkylated open-chain and cyclic hydrocarbons, while MOAHs are alkylated aromatic molecules. Ceramides, originating from fatty acids and sphingosine in high-fat diets, can result from excess fat metabolism and overheating. The research methodology involved gap analysis, literature collection, criteria-based sorting, screening, and conceptual design creation, analyzing around 50 selected journals and supplementary sources. Major sources of MOSH and MOAH contamination are identified as packaging material migrations, particularly from paper packaging. Analytical strategies include HPLC, GC, and FID for contaminants and HPLC, MS/MS, and TLC for ceramides. Despite ceramide benefits, such as detection methods, they may induce drug resistance and lip toxicity. In summary, this research delves into the contamination caused by greases, packaging materials, and oil-based handling, emphasizing variables contributing to compound accumulation, long-term health risks, and analyzing sources, explanatory strategies, and associated health implications (Bonifasius Rahmantyo, 2022).

Addressing research gaps identified by Ahmad et al. (2019), this study lacks specific details on Hazard Analysis and Critical Control Point (HACCP) methods for reducing MOSH levels in Crude Palm Oil (CPO) production. While noting lower MOSH levels in HACCP certified Mills, the study covers only two Mills in Malaysia, requiring broader research to validate consistency across locations. The absence of specific HACCP methods information calls for further investigation to understand their role and identify additional measures to prevent contamination in CPO production (Ahmad, H., Noor, A.M., Ahmad Sabri, December 2019).

3. Research Model and Hypotheses

Theories that involved with, Qualitative study on hydrocarbon contamination in CPO: - Case study of Palm Oil Mill in Sumatera Indonesia.

Environmental Justice Theory could be a viewpoint that highlights the unequal distribution of natural dangers, benefits, and hurts over diverse social groups. Within the setting of hydrocarbon contamination in a palm oil process in Sumatra, Indonesia. This theory explores whether certain communities, especially marginalized and low income populations, are more exposed to hydrocarbon contamination due to their nearness to the palm oil process. This can be due to components like constrained get to assets, need of political impact, and authentic designs of separation. It also investigates how hydrocarbon contamination influences the wellbeing and wellbeing of neighborhood residents. Are there hoisted rates of respiratory sicknesses, skin conditions, or other wellbeing issues in these communities? Understanding the wellbeing impacts can shed light on the seriousness of the issue and the require for relief measures.

Environmental Justice Theory can reveal designs of imbalance and raise mindfulness approximately the require for reasonable and fair natural management practices. This point of view can contribute to approach proposals, community strengthening, and a broader understanding of the complexities encompassing hydrocarbon contamination within the region.

Political Environment theory to your qualitative study on hydrocarbon contamination in a Sumatera palm oil process setting offers a comprehensive lens to scrutinize the interaction between control flow, political strengths, and financial interface. This system empowers the examination of how these variables shape natural issues, such as hydrocarbon contamination, by uncovering the impact of partners including palm oil industry on-screen characters, legislative approaches, and nearby communities. By delving into clashes, disparities, accounts, and backing efforts, Political Ecology enlightens the complex web of intuitive that decide contamination's degree and administration, giving a nuanced understanding of its effect on both the environment and affected communities.

Risk Perception and Communication theory explores how individuals see and communicate dangers related to natural dangers. In this setting, analysts might examine how laborers within the palm oil process, nearby residents, and partners get it and communicate the dangers related with hydrocarbon contamination, This Theory can offer assistance reveal not as it were the specialized perspectives of risk management like those laid out in HACCP, hazard evaluation, and GMP, but moreover the human component of how these approaches are caught on, communicated, and coordinates into the everyday practices of specialists and stakeholders. This inclusive approach can give important experiences into progressing hazard management procedures, improving communication, and advancing a more comprehensive understanding of the potential threats related with hydrocarbon contamination within the palm oil process settings.

Theoretical framework

The research incorporates key concepts from the Theory of Risk Perception and Communication, focusing on strategies to manage mineral oil hydrocarbon (MOSCH) contamination in Crude Palm Oil (CPO) production.

1. Hazard Analysis and Critical Control Point (HACCP): The study compares MOSH levels in HACCP-certified and non-certified palm oil mills. HACCP is a systematic approach to identify, evaluate, and control food safety hazards, consisting of seven principles, including hazard analysis, critical control points identification, critical limits establishment, monitoring procedures, corrective actions, verification procedures, and record-keeping. The HACCP system is referenced for controlling and preventing MOSH contamination in CPO production.

2. Risk Assessment and Management: The study applies risk assessment and management principles to evaluate and mitigate potential dangers associated with MOSH contamination in CPO. Risk assessment involves identifying hazards, estimating their likelihood and severity, and determining acceptable risk levels. Risk management focuses on implementing controls to reduce or eliminate identified risks. The study refers to a HACCP worksheet identifying potential oil and grease leakage in palm oil mills as an example of risk management (see Figure 3 in the appendix).

3. Good Manufacturing Practices (GMP): The study emphasizes the importance of implementing good management practices and regular maintenance and cleaning procedures to minimize the risk of MOSH contamination. GMP refers to the practices and procedures

required to ensure products are consistently produced and controlled according to quality standards. The study suggests that GMP principles may have been considered to establish guidelines for CPO production to prevent MOSH contamination.

4. Methodology

Research methodology for mitigating contamination in Palm Oil Mills includes the following steps beneath.

This study employed an exploratory research design to comprehensively investigate contamination risks in Palm Oil Mills and recommend effective strategies for improvement. Data collection involved a mixed-methods approach, combining primary data from interviews and field observations with secondary data from existing literature. Eight Palm Oil Mills in Sumatera, Indonesia, were selected for the study, and interviews were conducted with Mill Managers to gather insights on safety protocols, contamination prevention practices, and challenges related to hydrocarbon contamination in Crude Palm Oil (CPO) production. Additionally, field observations were carried out to further scrutinize the identified areas and identify viable solutions to mitigate contamination.

The research adopted a pragmatic model, focusing on practical solutions while considering the subjective perspectives of plant managers. Both qualitative and quantitative data were collected to provide a comprehensive exploration of contamination issues, with qualitative data offering contextual information and quantitative data allowing for comparisons with regulatory limits. The implementation of the Hazard Analysis and Critical Control Point (HACCP) system was a key aspect of the study, aiming to manage pollution risks by identifying critical control points and establishing critical limits. The effectiveness of the HACCP system and other control measures was verified through testing and compared with established critical limits.

Ethical considerations were taken into account throughout the study, including obtaining consent from participants and ensuring data protection. Data analysis was conducted using thematic analysis to identify key themes related to contamination reduction. Limitations of the study included time constraints for interviews and the focus on Sumatera Mills. The research methodology was underpinned by an extensive literature review, which informed the identification of potential areas for improvement in Palm Oil Mill operations. The goal was to contribute to the development of effective strategies that enhance the safety and quality of Palm Oil production, ensuring that Palm Oil products are safe and of high quality for both consumer safety and the reputation of the Palm Oil industry.

Data Collection: -
The information was collected from eight different Palm Oil Mills, and samples were taken at different stages of Palm Oil processing, including FFB from Road Tanker (Truck), FFB after sterilizer, fruits after threshing, condensate oil (COND), oil in bunch press, 1st pressed oil CPO (mixing), sludge recovered CPO, light phase decanter, and CPO Production/composite tank. The samples were tested by either the Malaysia or Singapore Lab.
The system and guidelines for implementing Hazard Analysis and Critical Control Point (HACCP) methods used: - The Hazard Analysis and Critical Control Point (HACCP) system is a science centered and orderly approach to recognizing and controlling potential risks in food production. The system can be connected in Palm Oil Plants to ensure the safety and quality of Palm Oil production. HACCP

includes identifying particular dangers and measures for their control to avoid food contamination. The system can oblige changes in equipment plan, processing strategies, and innovative developments.

Mill	Compliance Summary	Non-Compliance Details	Limit Parameters
1	Mixed compliance. Some samples exceeded limits for MOSH C16-35 and MOAH C10-50.	FFB Road Tanker (MOSH C16-35), CPO from sludge (MOSH C16-35)	MOSH: 20mg/1kg, MOAH: 2mg/1kg
2	Generally compliant with MOAH; non-compliance with MOSH C16-35 in CPO from sludge.	CPO from sludge (MOSH C16-35)	MOSH: 20mg/1kg, MOAH: 2mg/1kg
3	Compliance with MOAH; non-compliance with MOSH C16-35 in FFB after sterilization.	FFB after sterilization (MOSH C16-35)	MOSH: 20mg/1kg, MOAH: 2mg/1kg
4	Generally compliant with MOAH; non-compliance with MOSH C16-35 in CPO from sludge.	CPO from sludge (MOSH C16-35)	MOSH: 20mg/1kg, MOAH: 2mg/1kg
5	Consistently compliant with both MOAH and MOSH at all sampling points.	-	MOSH: 20mg/1kg, MOAH: 2mg/1kg
6	Consistently compliant with both MOAH and MOSH at all sampling points.	-	MOSH: 20mg/1kg, MOAH: 2mg/1kg
7	Consistently compliant with both MOAH and MOSH at all sampling points.	-	MOSH: 20mg/1kg, MOAH: 2mg/1kg
8	Consistently compliant with both MOAH and MOSH at all sampling points.	-	MOSH: 20mg/1kg, MOAH: 2mg/1kg

5. Data Analysis and Results

The data analysis showed that some samples exceeded the maximum allowable levels of Palm oil, MOSH C16-35, and MOAH C10-50. For example, in Mill 1, the FFB from Road Tanker (Truck) sample had a level of 46.7ppm Palm oil, which exceeded the maximum allowable level. Similarly, in Mill 2, the sludge recovered CPO sample had a level of 29.6ppm MOSH C16-35, which exceeded the maximum allowable level. However, no sample exceeded the maximum allowable level of MOAH C10-50. It's important to note that compliance with the maximum allowable levels of MOSH and MOAH varies by sampling point, so each sample should be evaluated individually. (Reference in Appendix section at 8 Mills MOSH MOAH ANALYSIS REPORT)

Overall Conclusion: -

The examination of compliance with MOSH and MOAH levels across eight Palm Oil mills revealed varying results. Mills 1, 3, and 4 showed occasional non-compliance with MOSH C16-35, while Mill 2 demonstrated good compliance with MOAH levels but had issues

with MOSH C16-35. Mills 5, 6, 7, and 8 exhibited excellent compliance with both MOAH and MOSH levels. Overall, occasional non-compliance with MOSH C16-35 was observed in CPO samples recovered from sludge across various mills. To ensure sustainable Palm Oil production and minimize environmental and public health impacts, all mills should address non-compliance occurrences, maintain consistent monitoring, and adhere to best practices, including standard testing, quality control, and equipment maintenance. Compliance parameters are set at 20mg/1kg for MOSH and 2mg/1kg for MOAH according to the Scientific Committee of the Federal Agency for the Safety of the Food Chain (FASFC).

5.1 Interview samples

Based on Roundtable on Sustainable Palm Oil (RSPO) auditor interview results: -

The insights gained from conversing with the RSPO auditor shed light on the worries and requirements of environmental advocacy groups and NGOs regarding the impact of the Palm Oil sector on the environment and public health in Sumatra. To obtain certification from RSPO, companies must adhere to the environmental and social standards put forth by the organization. The RSPO auditor expressed genuine concern about the effect of hydrocarbon pollution on both public health and the environment within the Palm Oil industry. The RSPO has established standards aimed at promoting sustainable Palm Oil production which encompass factors related to environmental conservation and social welfare. The given standards ensure that the production of Palm Oil does not result in any detrimental environmental impact or negative effects on the neighboring communities. The RSPO assessor advocated preventive measures to prevent contamination, such as enhancing waste management methods and enforcing stricter rules on hazardous chemical use and distribution. The RSPO auditor has also suggested intensifying the supervision and examination of soil, water, and air quality in locations where pollution has occurred to ensure that effective remedial actions are implemented. The RSPO auditor suggested a variety of measures to tackle these issues, including advocating for transparency and accountability, implementing eco-friendlier production techniques, advocating for policy reforms, endorsing sustainable practices for Palm Oil production, and backing NGOs dedicated to safeguarding both nature and human welfare. These endeavors can aid in promoting knowledge of the impact of hydrocarbon pollution and reinforce initiatives in promoting sustainable measures. Thematic analysis was applied to the interview findings to identify major themes and recurring patterns that emerged within the responses. The results were analyzed with regard to the research queries to offer a better understanding of the interests and requirements of environmental advocacy organizations and non-governmental organizations regarding the Sumatra Palm Oil sector and the consequences of hydrocarbon pollution on public health and the ecosystem. The study's limitations include limited sample size, possible biases in the RSPO auditor, and the study's narrow scope on the Palm Oil sector in Sumatra. Refer to Appendix (Interview Questions and answers to RSPO Auditor)

Based on the Palm Oil Managers interview results,

The study included Eight Palm Oil Mill managers who were interviewed to assemble data on quality control measures to prevent hydrocarbon contamination in CPO production. The information was collected through semi structured interviews that secured topics such as processes and practices for ensuring the quality and safety of CPO production, lubricants and chemicals utilized in machinery for CPO extraction, measures taken to prevent contamination of the final item, and challenges and limitations in implementing quality control measures. The interview transcripts were looked into and coded to recognize common subjects and patterns related to quality

control measures for CPO production. The results showed that all the Palm Oil Mills had set up measures to ensure the safety and quality of CPO production. They had implemented comprehensive traceability systems to track the origin and movement of palm fruit throughout the production process, conducted regular testing of the CPO, and implemented measures to prevent hydrocarbon contamination, such as using food grade lubricants and hydraulic fluids, and conducting regular inspections of machinery and equipment. However, there were challenges and limitations in implementing quality control measures, such as poor communication and coordination between workers, reliance on third party suppliers for inputs, and high turnover rates and staffing shortages. Ethical Considerations, the study was conducted in accordance with the ethical guidelines for research involving human participants. The participants were provided with informed consent, and their privacy and confidentiality were ensured throughout the study. The study highlights the importance of implementing effective quality control measures to prevent hydrocarbon contamination in CPO production. The findings provide insights into the current practices and challenges faced by Palm Oil Mills in ensuring the safety and quality of CPO production, and suggest areas for improvement in quality control measures. Samples are collected from the 9 points taken from Mill Stations, from: - FFB from truck, FFB after Sterilizer, Fruit after threshing, Condensate oil, Oil in bunch press, press oil CPO, sludge recovered oil, light phase decanter, CPO Composite tank. The data was collected from eight different Palm Oil Mills. The Mills were chosen based on their location, accessibility, and willingness to participate in the study. The samples were taken at different stages of Palm Oil processing, including FFB from Road Tanker (Truck), FFB after sterilizer, fruits after threshing, condensate oil (COND), oil in bunch press, 1st pressed oil CPO (mixing), sludge recovered CPO, light phase decanter, and CPO Production/composite tank. These stages were chosen because they are critical in the Palm Oil production process, and contaminants can be introduced at each stage. The samples were collected by trained personnel using appropriate sampling procedures and equipment to avoid contamination. The samples were then transported to the laboratory in sterile containers and stored at the required temperature until analysis. The samples were tested for different contaminants, including Palm Oil max at 20ppm, MOSH C16-35, and MOAH C10-50. The analysis was conducted by either the Malaysia Lab or Singapore Lab, which are accredited and recognized laboratories in the Palm Oil industry. The choice of laboratory depended on their expertise, availability, and proximity to the Mills. The results obtained from the analysis were recorded in a table, which includes the Mill number, type of sterilizer, date, and the laboratory that conducted the analysis. The table also shows the concentration of each contaminant in each sample tested. Reference in Appendix section at 8 Mills MOSH MOAH ANALYSIS REPORT

Based on the Managers answer there is qualitative method used,

Sending to lab test on PPM of contamination in MOSH and MOAH. Sending samples for laboratory testing to determine the parts per Million (PPM) of contamination in mineral oil saturated hydrocarbons (MOSH) and mineral oil aromatic hydrocarbons (MOAH) is a good practice to ensure the safety and quality of food products, including palm oil. MOSH and MOAH are types of mineral oil contaminants that can be found in food products, including palm oil, as a result of contact with machinery or packaging materials that contain mineral oils. These contaminants can potentially pose health risks if consumed in high concentrations over a long period of time. Laboratory testing can help to determine the PPM of MOSH and MOAH in palm oil, which can then be compared to regulatory limits to determine if the product is safe for consumption. If the PPM of MOSH and MOAH in Palm Oil exceeds regulatory limits, corrective actions can be taken to prevent contamination in the future and ensure the safety of the product. (Anna stauf, May 2020) It is important to work with a reputable laboratory that has experience in testing for MOSH and MOAH in food products, and to follow proper sampling and testing procedures to ensure accurate and reliable results. The use of validated testing methods and equipment is also important to

ensure the quality of the testing process Sampling bottle (avoid contact with any plastic material), 20g oil sample is enough for testing and Preferably glass bottle with aluminum foil cover before the cap as shown in (Picture 1, Figure 1,2 &3at Appendix).

The Major findings states that: -

Currently, there is no local regulatory standard in place that establishes maximum levels for Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH). However, European authorities have issued several recommendations in this regard. This information allows the Palm Oil Mill located in Sumatera, Indonesia, under my supervision, to be aware of and ensure that our production processes adhere to the best practices and references for mitigating MOSH and MOAH. We place significant importance on strictly following these protocols throughout the entire Palm Oil Mill process. Importers from European countries impose specific requirements for MOSH and MOAH levels in crude Palm Oil (CPO), with a parameter of 20mg/1kg oil for MOSH and 2mg/1kg oil for MOAH.

The MOSH fraction (C16-C35) denotes to a group of hydrocarbons called mineral oil saturated hydrocarbons, which are normally found in food due to contamination from packaging materials and other sources. These hydrocarbons are of concern since they have been appeared to have potential health impacts, such as accumulation in organs and tissues, and may cause irritation. The reason of these activity edges is to guarantee that the levels of MOSH in food don't posture a hazard to human wellbeing. Food makers and producers are dependable for guaranteeing that their items comply with these activity limits. This subjective report points to describe the methodology utilized to gather and analyze information related to the levels of Palm oil, MOSH C16-35, and MOAH C10-50 in several stages of Palm Oil handling in eight distinctive plants. The information was collected on distinctive dates from April 2020 to April 2021, and the tests were tried by either the Malaysia Lab or Singapore lab. Refer to Appendix (Qualitative research Interview with Mill Managers & Estate Managers).

Structured interviews with representatives from each of the four Palm Oil Estate Managers.

This research study aims to investigate the measures taken by four different FFB (Fresh Fruit Bunch) suppliers to ensure the quality and safety of the Crude Palm Oil (CPO) they supply or trade. Specifically, this study focuses on the measures taken by FFB suppliers from KSD, MBE, CDE, and KWS to monitor and prevent potential sources of hydrocarbon contamination in the CPO they handle. To achieve this objective, a qualitative research method was employed, which involved conducting semi-structured interviews with representatives from each of the four FFB suppliers. The interview questions were developed based on the research objective and were designed to gather detailed information on the suppliers' quality control processes, testing procedures, and communication strategies related to CPO safety and quality. The study used purposive sampling to select the participants, which involved selecting individuals who had direct involvement in the suppliers' quality control and safety procedures. The interviews were conducted via telephone or video conferencing, with the participant’s consent and were recorded and transcribed for analysis. The collected data was analyzed using content analysis, which involved the identification of common themes and patterns across the interviews. The themes were organized and presented in a narrative form, highlighting the similarities and differences in the measures taken by the four Palm Oil suppliers. Ethical considerations were taken into account throughout the study, ensuring that the participants' anonymity and confidentiality were maintained, and their

consent was obtained before conducting the interviews. Overall, this research study provides insight into the measures taken by FFB suppliers from KSD, MBE, CDE, and KWS to ensure the quality and safety of the CPO they supply or trade, specifically in relation to monitoring and preventing potential sources of hydrocarbon contamination. The findings of this study can be used to inform and improve the Palm Oil industry's standards and practices related to CPO safety and quality. Refer to Appendix (Qualitative research Interview with Mill Managers & Estate Managers.)

5.2 Missing Data Analysis, In the examination of compliance with MOSH and MOAH levels in Palm Oil generation across eight Mills, it was noted that Mill 1 exhibited non-compliance for both MOSH C16-35 and MOAH C10-50 in the FFB from the Road Tanker show and the CPO sample recovered from the sludge. The missing data in Mill 1 was attributed to technical issues during laboratory analysis, specifically for MOSH C16-35 and MOAH C10-50 tests in these particular samples. This absence of data may compromise the overall assessment of contamination levels, particularly regarding compliance with MOSH and MOAH levels at specific sampling points. To address this, potential imputation techniques, such as multiple imputation, could be explored to estimate the missing values based on data from other Mills or sampling points. Sensitivity analyses should be conducted to evaluate the robustness of conclusions by considering different scenarios of imputed values and their impact on assessments of compliance. Recommendations for future research include enhanced protocols for data collection and analysis to minimize technical issues during testing and ensure data reliability. Despite these challenges introduced by missing data, the study emphasizes transparency by acknowledging limitations and proposing measures to address data gaps, ensuring the integrity of the overall findings.

5.3 Assessment of Outliers, the study focused on addressing the research objectives related to the sources of contamination in Crude Palm Oil (CPO) processing, permissible levels of Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH) in foods according to regulations, and measures to mitigate or lower the contamination levels. Sources of contamination, the study identified machine oil and hydraulic oils used during CPO processing as sources of contamination. To prevent contamination, it is important to properly maintain equipment, regularly check and change the oils used, and implement good manufacturing and hygiene practices. In analysis of eight plants showed varying degrees of compliance with the maximum allowable levels of MOSH and MOAH. While some Mills demonstrated excellent compliance at all sampling points, others had isolated instances of non-compliance. The findings underline the importance of continued monitoring and compliance with industry standards to ensure sustainable Palm Oil production and reduce potential environmental and public health risks associated with hydrocarbon contamination. Permissible levels of MOSH and MOAH, the study highlighted the need to comply with the permissible levels of MOSH and MOAH in foods based on regulations and laws. Regular testing and monitoring of CPO for contaminants, including MOSH and MOAH, using analytical methods such as gas chromatography or mass spectrometry, was recommended. Mitigate or lower contamination, possible solutions based on industry practices included using alternative lubricants that do not contain mineral oils, implementing a robust maintenance and inspection program, proper waste management practices.

6.0 Recommendation: -

Based on first research objectives that aims to identify the sources of mineral oil contamination in CPO. To address this issue, I recommend the **implementation of appropriate maintenance protocols** for the equipment deployed in the processing of Crude Palm Oil (CPO) is of paramount importance. One must perform routine inspections and replacements of the various oils utilized in the equipment. It is recommended to establish a comprehensive system of record keeping in order to effectively monitor and hold

accountable maintenance activities. This system should entail the meticulous documentation of pertinent details such as dates, procedures executed, and identified issues. **Recommendation no.2** for 1st objective is to Adherence **to Good Manufacturing Practices (GMP),** In order to maintain appropriate levels of cleanliness and hygiene within processing facilities to mitigate the source of MOH, it is crucial to adhere to the principles of good manufacturing practices (GMP). Regular training sessions aligns with your objective to identify sources of contamination, it must be conducted for employees to facilitate comprehension and adherence to Good Manufacturing Practice (GMP) standards. **Research Objective 2** is to explore the permissible levels of Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH) in food products. It is recommended to conduct periodic assessments and surveillance of CPO for impurities, specifically MOSH and MOAH contaminants. It is imperative to adhere to regulatory norms and acceptable thresholds of Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH). Limit parameter of 20mg/1kg oil for MOSH and 2mg/1kg oil for MOAH Based on Scientific Committee of the Federal Agency for the Safety of the Food Chain (FASFC) and EFSA. It is necessary to remain abreast of pertinent regulations and laws, and adapt processing protocols accordingly in order to adhere to or exceed the prescribed standards. It is recommended to advocate for more **stringent standards** and regulations within the Palm Oil industry.

Contribution of the research:

Penetration for New market at Europe for CPO products from Sumatera Mills has been an ongoing journey ever since started the application of the theories based on this research.

7. Conclusion:

The study contributes to understanding the sources of contamination in Crude Palm Oil (CPO) processing, the permissible levels of Mineral Oil Saturated Hydrocarbons (MOSH) and Mineral Oil Aromatic Hydrocarbons (MOAH), and potential measures to mitigate or lower the contamination levels. Implementing the recommended solutions can enhance the safety and quality of CPO, ensure compliance with regulations, and promote sustainability in the Palm Oil Industry.

Collaboration among stakeholders and the implementation of stronger regulations are crucial for the successful implementation of the Hazard Analysis and Critical Control Point (HACCP) system (refer to appendix for the Sequence of Application of HACCP). Proper equipment maintenance and adherence to Good Manufacturing Practices (GMPs) play a pivotal role in preventing contamination of CPO with machine oil and hydraulic oils, ensuring the safety and quality of the product.

The qualitative study on hydrocarbon contamination in CPO highlights the significant environmental and health impacts of this issue, emphasizing the need for stricter regulations, monitoring mechanisms, and stakeholder education. The research provides valuable insights for policymakers and industry stakeholders to develop sustainable practices that minimize hydrocarbon contamination. Furthermore, the research underscores the importance of closely monitoring and improving techniques used in Palm Oil processing to comply with the highest acceptable levels of potentially harmful elements and ensure the protection and excellence of Palm Oil products. Industry stakeholders must prioritize taking proactive measures to safeguard consumer wellbeing and preserve the Palm Oil Industry's reputation.

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