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What Does Human Factor Analysis Tell Us About Mineral Oil Hydrocarbon Contamination?

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Abstract

Mineral oil hydrocarbon (MOH) contamination in the vegetable oils and fats supply chain has gained stakeholders' attention due to health risk concerns based on the European Food Safety Authority's (EFSA) risk assessment. Although the potential source of MOH introduction in vegetable oils is already known, the human causal factors were not attentively investigated. Hence, the present study aims to gauge the impact of food safety knowledge, maintenance programmes and training effectiveness on the food safety practices of food handlers employed in palm oil mills (POM) in Johor, Malaysia. One hundred cross-sectional samples were collected from POM using a validated survey questionnaire. Descriptive statistics were used for demographic information analysis, while partial least squares structural equation modeling (PLS-SEM), a second-generation statistical tool was applied for predictive-causal design testing. Results showed majority of the POM food handlers were not trained on good milling practice. The PLS-SEM analysis illustrated that maintenance programmes and training effectiveness have a significant and positive impact on POM food handlers' food safety practices. Meanwhile, food safety knowledge did not reveal a significant impact on food safety practices. Predictive causal analysis confirmed the model has strong predictive power for food safety practices. Overall, the present study highlighted the role of human factors that are latent in an organisation which needs to be emphasised by palm oil mill management in mitigating MOH risk.

Keywords: *Food Safety Knowledge, Maintenance Programme, Training Effectiveness, Food Safety Practice, Palm Oil Mill, Mineral Oil Hydrocarbon.*

Introduction

Palm oil is the main contributor of economic development worldwide from the aspects of production, export, and usage, surpassing other oilseed crops like soyabean, rapeseed, and sunflower. In fact, in 2021, its global production reached 72.96 million metric tonnes (United States Department of Agriculture [USDA], 2023). Besides that, since 2019, palm oil consistently ranks as the topmost oil-bearing crop contributor. Approximately 55% of the world's exports of major vegetable oils have been dominated by palm oil since 2019 (USDA, 2023), which contributed USD 39 billion to the global gross domestic product (GDP) in 2016. The palm oil industry has also played a significant role for small holders globally as their main source of livelihood, and it has also created an estimated 2.9 million jobs in importing countries for people employed in palm oil industries producing palm-based food ingredients (Basiron, 2016).

In Malaysia, palm oil is the primary agricultural commodity within manufacturing industries that has contributed 35.2% to the nation's GDP in 2021 and comprises upstream, midstream, and downstream sectors (Department of Statistics Malaysia [DOSM], 2022). The unique characteristics of palm oil, such as its

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rich source of phytonutrients and higher oxidation stability, in addition to the variety of co-fractions derived from palm oil, such as palm stearin, palm olein, glycerol, fatty acids, and fatty alcohols, serve as a basic resource for numerous applications in the global value chain for food and non-food usage. Specifically, 82% of palm oil usage in Southeast Asia is mainly accounted for by domestic food production (USDA, 2023), so the sustainability of this industry has significant importance in ensuring global food security.

Approximately 1 of 10 people worldwide become sick and eventually die, resulting in 420,000 death occurrences each year as a result of taking food that is contaminated microbiologically and chemically (WHO, 2022). 42% of reported incidents of food contamination are recorded in the Southeast Asia region alone (WHO, 2015). Food safety is widely acknowledged as the main global public health issue given that the safety of food is a crucial factor in determining human well-being. In Malaysia, recalls arising from food safety incidents drastically increased by 40% from 2020 to 2021, as reported by the Ministry of Health (MOH, 2021). Although this percentage is concerning, the specific food business sectors involved in the recall were not reported, so the extent of cases stemming from the palm oil industry remains unknown.

Despite being the nation's major source of export revenue, the palm oil industry in Malaysia has been plagued with various food safety contamination issues (Naidu & Moorthy, 2021). The presence of mineral oil hydrocarbon (MOH) contamination in vegetable oils and fats has become a growing concern for food safety recently, especially among many stakeholders as a result of possible health hazards based on European Food Safety Authority (EFSA)'s published scientific view associated with MOH in food. As confirmed by the EFSA, MOH in food contains genotoxic components that are dangerous to humans' health-wise (European Food Safety Authority [EFSA], 2023; EFSA, 2012). MOH, comprising mineral oil saturated hydrocarbon (MOSH) and mineral oil aromatic hydrocarbon (MOAH), originates from crude mineral oil of petrogenic origin. MOH occurrence in various foods has been reported since the early 1990's; however, the issue draws global attention following Ukraine's sunflower oil contamination incidence in 2008. Almost all foods contain MOH (Grob, 2018; Grob & Biedermann, 2019), and a report by Foodwatch (2021) revealed 92% of numerous foods detected with MOH above the quantification limit. Among these, edible oils are the most seriously MOH-contaminated food (Grob, 2018), which includes palm oil (Ahmad et al., 2019; Stauff et al., 2020). Due to its classification as an industrial contaminant by EFSA and its potential harm to human health, the presence of MOH in palm oil has prompted industry players to address the risk of contamination.

In this regard, most of the previous food safety research on MOH has emphasised aspects of identifying potential sources of contamination with prevention measures recommendations (Grob, 2018; Grob & Biedermann, 2019; Jaen et al., 2022), disparity in viewpoints of analytical methodology (Ursol et al., 2023; Wagner & Oellig, 2019; Weber et al., 2018), and toxicological assessment (Bevan et al., 2020; Grob, 2018; Grob, 2018a; Cravedi et al., 2017). In addition, various guidelines have been issued regarding the control of MOH existence in vegetable oils and fats intended for consumption. These include the Code of Practice (COP) established by the Federation for European Oil and Proteinmeal Industry (FEDIOL) and the Code of Good Milling Practice for Palm Oil Mills developed by the Malaysian Palm Oil Board (MPOB). Despite efforts on mitigation measures, the problem has yet to be solved (DGF, 2023) as evidenced by an increased trend of MOH detection cases in various foods including palm oil by 150% from 2020 until 2023, reported by the Rapid Alert System for Food and Feed (RASFF) (EU, n.d.). While knowledge attained from previous research has significantly propelled our understanding of this field, it also sparks new questions to further explore the underlying factors influencing MOH occurrences in palm oil.

Despite the established COP and operational mitigation measures as recommended by scholars surrounding MOH, even a well-planned food safety management system can undermine the expected outcome unless we take into account human factors in an organisation that influence food safety practices, considering research has found that the majority of the food safety incidents are attributed to human factors (Liu et al., 2015; Walsh & Leva, 2019). MOH contamination at palm oil mills (POM) was already pointed out by Van Duijn and Den Dekker (2010) and Ahmad et al. (2019), and these contaminants, especially the long-chain hydrocarbon (>C24) are not able to be removed at downstream processes (Stauff et al., 2020). Further to this, most operational activities at POM involve human activity, including the receiving of fresh fruit bunches (FFB), unloading into the receiving ramp, upkeep of processing equipment cleanliness, maintenance of processing equipment, and many others. Inappropriate food handling practices by handlers have been responsible for foodborne outbreaks worldwide (Todd et al., 2007), and contamination-contributing factors (Gould et al., 2013) are commonly linked with foodborne outbreaks. Therefore, food handlers that directly in contact with food and food contact surfaces throughout palm oil production play an essential role in ensuring food safety (Isoni Auad et al., 2019).

The execution of effective mitigation strategies to control the processing environment and produce safe food begins by addressing human factors in an organisation that led to food safety incidents, as asserted by Da Cunha et al. (2022) and Todd et al. (2007). Food safety incidents are mainly due to human factors motivated by active failures or latent conditions that are inadequately addressed and controlled (Rodriguez-Perez, 2023). Active failure is a departure from desired practices that can have an immediate negative impact on the food safety system due to errors, mistakes, and violations, while latent conditions are factors that have been dormant in an organisation for a long time and, if unaddressed, trigger inadequate food safety practices that eventually lead to food safety incidents. According to Soon et al. (2020), although active failure factors are detailed for most food safety incidents, limited information has been analysed on the latent factors.

This is true in the case of MOH contamination in edible oils, whereby past research has suggested that the probable source of contamination is lubricating oil used at machinery (Bevan et al., 2020; Grob, 2018; Grob, 2008); however, latent factors leading to such incidental contamination were not investigated. Similarly, food transportation, which was previously used for mineral oil products, was identified as another source of MOH contamination (Grob, 2018); nevertheless, the active and latent factors were not addressed. Given the importance of human role interventions that influence food safety practices in preventing MOH incidents, the causative human factors need due attention since limited literature integrates human factors into food safety management systems (Soon et al., 2020; Shirani & Demichela., 2015; Milios et al., 2012).

In this perspective, although MOH contamination at POM has already been highlighted in previous research (Van Duijn & Den Dekker., 2010; Ahmad et al., 2019), along with widespread concern about potential health risks, uncertainty on knowledge gaps remains (Hochegger et al., 2021). Furthermore, food safety knowledge among the reasons for knowledge-based mistakes is still prevalent, as highlighted by Khaleefah et al. (2020), Ngoc et al. (2020), and Oduro-Yeboah et al. (2020), though past studies have investigated the same in different food settings, for example, food truck vendors, street food vendors, food service staff, and household food handlers. Thus, the occurrence of MOH incidents at POM could be explained by POM's food handler's low-level exposure to MOH. As such, effective food safety training being a latent factor is imperative to enhance food handlers' knowledge (Griffith & Motarjemi, 2023) in order to reduce the prevalence of MOH incidents. Aside from this, a previous study by Moerman (2017) highlighted the importance of maintenance programmes, especially in the food industry, in preventing food contamination. Therefore, this study aimed to examine how food safety knowledge, maintenance programmes, and effectiveness of training among POM food handlers impact their food safety practices in regard to the MOH.

Literature Review and Hypotheses

Food Safety Knowledge and Food Safety Practices

Knowledge is described as cognitive contact with reality arising out of an act of intellectual virtue (Zagzebski, 1999). In the context of food safety, food safety knowledge measures food handlers awareness and understanding in dealing with and executing activities in a safe food manner (Rifat et al., 2022). It is challenging to enhance food safety when knowledge on food safety is lacking. Hence, food safety knowledge is an essential ingredient in food safety to ensure safe food practices are followed. Food safety practices refer to the specific actions and precautions implemented to handle, prepare, and store food in order to minimise the possibility of food contamination. One driver of the pronounced increase in global burden foodborne outbreaks is food preparation in unsafe practices (Todd et al., 2007), whereby when food is not prepared according to safe practices at any point of the food production chain, it will lead to contaminated food, which may cause public health problems (Desye et al., 2023). The prevalence of inadequate food safety practices remains significantly high (Tamiru et al., 2022), and prior research elucidates the role of food safety knowledge and food safety practices. As an example, Tamiru et al. (2022) highlighted limited knowledge of food safety among food handlers in Mettu and Bedelle towns increases the likelihood of poor food safety practices by 2.32 times. Aside from this, Isoni Auad et al. (2019) asserted that food truck food handlers with low food safety knowledge are likely to exhibit practices resulting in food contamination and are at high risk of causing foodborne disease. Similarly, Swinehart and Feng (2023) showed lower food safety knowledge among U.S. consumers who tended to engage in risky tree nut food safety practices. Therefore, food handlers' practices are influenced by their knowledge of food safety (Halim-Lim et al., 2023).

While possessing strong knowledge does not ensure good practice, it is a crucial contributing component in promoting better food handling practices (Tesfaye & Tegene, 2020). It provides food handlers with guidance to effectively assess and make informed decisions regarding safe food practices. Past studies on knowledge and practice emphasised characteristics such as time and temperature control, cross contamination, personnel hygiene, and others that cause foodborne outbreaks, mainly due to microbiological hazards. However, these characteristics or indicators are not relevant within the context of MOH since it is a chemical contaminant that arose from improper manufacturing practices. Dzudzor and Gerber (2023) asserted that unsafe food can also result from chemical contaminants. Therefore, within the scope of this research, food safety knowledge examines how much the food handlers understand MOH, aware of MOH dangers, and able to identify possible sources of contamination, as well as practices of cleanliness which serve as an indication of food safety practices. At present, there is a lack of literature that evaluates food safety knowledge and practice with regards to MOH in spite of food safety alerts and recalls which occurred lately. Thus, drawing on the evidence from past literature that food safety knowledge influences food handlers' food safety practices, the hypotheses below were proposed in this study:

H1: *Food safety knowledge significantly and positively impact POM food handler's food safety practices.*

Maintenance Programmes and Food Safety Practices

Within the food safety context, the maintenance programme refers to a documented plan that outlines the maintenance requirements encompassing maintenance procedures, inspection schedules, and other aspects of the food establishment to ensure continuous upkeep of equipment and structures. In the food industry, maintenance programmes are part of a good manufacturing practice (GMP) prerequisite programme that provides a framework for best practices in controlling food processing equipment for safe food production. Nevertheless, a well-established maintenance programme in the context of food safety does not confine itself to conventional maintenance approaches such as having written procedures and a scheduled maintenance plan. Moerman (2017) and Aarnisalo et al. (2006) also emphasised personnel competency since it is crucial to ascertain that maintenance activities are conducted in a safe manner that minimises food contamination due to maintenance errors. Factors such as inadequate maintenance procedures, incompetent maintenance personnel, unhygienic maintenance practices (Ngadiman et al., 2016), and the unavailability of a lubricant condition monitoring plan (Whitby, 2022) prompted by a poor maintenance programme can have a significant impact on equipment performance, which jeopardises food safety systems.

Past studies have explained the influence of maintenance programme on food safety; for instance, Hasnan et al. (2022) highlighted that poor maintenance programmes accounted for 50% of GMP non-conformance among small and medium food processing companies and prominently resulted from the absence of maintenance procedures and schedules, which led to ineffective cleaning practices. Similarly, when a maintenance programme does not contain explicit information on how to perform the task in a safe food manner, for example, a post-maintenance procedure with inadequate hygienic requirements will lead to improper equipment cleaning practices, thus compromising the safety of the food produced (Moerman, 2017). The significance of maintenance programmes is true in the case of MOH since previous studies asserted lubrication activity as a potential source of MOH contamination in edible oil processing (Grob, 2018; Bevan et al., 2020; Grob, 2008; Jickells et al., 1994) resulted from poor lubrication practices (Moerman, 2017). The implication of maintenance programmes on safety was widely studied in industrial accidents, for example, Saleh et al. (2019) in helicopter accidents, Chan et al. (2022) in the construction industry, La Fata et al. (2023) in the manufacturing sector, and Yalcin et al. (2023) in chemical accidents. However, exploration between maintenance programmes and food safety practices is limited within the food setting, with the exception of the studies by Hasnan et al. (2022) and De Moraes et al. (2020), who contended there was no explicit relationship between maintenance and food waste reduction practices. Drawing the significance between maintenance programmes and food safety practices, this leads to the below hypotheses:

H2: *Maintenance programmes significantly and positively impact POM food handlers' food safety practices.*

Training Effectiveness and Food Safety Practices

Training effectiveness is another key factor that is indistinguishably associated with food handlers' engagement in exercising safe food practices. Generally, it comes with the belief that when training is delivered effectively, it will facilitate the efficient translation of knowledge, skills, and abilities gained from the training at the workplace that enable food handlers to perform their task in a safe food practice manner. El Hajjar and Alkhanaizi (2018) provided a definition of training effectiveness as the extent to which the outcomes of training effectively contribute to achieving a targeted end. Evaluating training effectiveness involves any effort of gathering information on the impact of a training programme and assessing its worth based on that information (Dahiya & Jha, 2011). Several scholarly articles, such as Desye et al. (2023), Malavi et al. (2021), Al-Kandari et al. (2019), Ncube et al. (2019), Shuvo (2018), and Adesokan et al. (2015) have acknowledged food safety training as a method which encourages good food safety practices. They have also exhibited significant positive relationship between the two variables.

A growing body of research, for example, Park et al. (2010), Da Cunha et al. (2014), Bou-Mitri et al. (2018), and Souza et al. (2018), criticised food safety training as not influencing food handlers' food safety practices since knowledge gained from training is not translated into actual work practice. Past studies in various segments of the food industry, for example, De Freitas and Stedefeldt (2022) and Tyler et al. (2015) in commercial restaurants, WHO (2022) in street food vendors, and Abdelhakim et al. (2018) in the aviation industry, emphasised that instead of focusing on providing training merely, institutionalising an effective training is regarded as a crucial element in influencing food safety practices. Fraser and Miller (2013) concluded that even with a plethora of training programmes, food safety training effectiveness is widely rated as poor to fair. Similar assertiveness is also highlighted by Reynolds and Dolasinski (2019), who stated that safe food practices begin with effective training. Thus, considering the role of training effectiveness in shaping safe food practices by food handlers and the scant empirical evidence on evaluating training effectiveness towards food safety practices (Yeargin et al., 2021), this leads to the below hypotheses:

H3: *Training effectiveness significantly and positively impacts POM food handlers' food safety practice.*

Materials and Methods

Target Population and Samples

The study focused on food handlers employed in POM as the target population. Food handlers are individuals involved directly in food processing, with direct interaction with food or surfaces in contact with food, and are responsible for managing food equipment (MOH, 2012). The selection of POM operating in Johor, Malaysia was based on its substantial contribution (29.5%) to the overall output of crude palm oil (CPO) in Peninsular Malaysia from 2020 to 2022 (as shown in Table 3.1). Therefore, it is essential to investigate this specific population. Within Johor, there are 63 POMs in ten districts, with the highest POMs located within Kluang district (MPOB, 2021); hence, food handlers within the POM in Kluang, Johor, were selected as samples in this study.

Table 3.1: CPO production volume in Peninsular Malaysia.

States	CPO production (tonnes)
Johor	8,978,667
Pahang	8,807,476
Perak	5,609,451
Negeri Sembilan	1,958,189
Selangor	1,530,811
Terengganu	1,378,536
Kelantan	988,488
Kedah	692,156
Others	503,452

Source: (MPOB, n.d)

Sampling Technique, Sample Size, and Data Collection

Purposive sampling was applied in this study to collect data from the POM's food handlers. There were two types of purposive sampling within the chosen non-probability sampling technique, which are judgement sampling and quota sampling. Judgement sampling was utilised as respondents were chosen according to specific criteria and their ability to offer the necessary information. Moreover, purposive sampling is suitable when the study aims to attain a targeted sample and maintaining proportional sampling is not the primary consideration (Bougie & Sekaran, 2019). While the intention of this study was to measure the mentioned variables, the required information could only be obtained from food handlers instead of non-food handlers; hence, rationalised the chosen sampling technique.

The sample size was chosen using power analysis, following the recommendations of Hair et al. (2017, 2018, 2019), Kline (2016), Ringle et al. (2018), and Uttley (2019). The power analysis was conducted using G*Power application version 3.1.9.6, which is widely regarded as the preferred software in social science and business research (Hair et al., 2014, 2017). In order to determine the accurate sample size in power analysis, information on effect size, level of significance (α), power, and number of predictors are required. Medium effect size f2= 0.15 (Cohen, 1988), alpha = 0.05, power = 0.80, and three predictors, considering the largest of the predictors in the model, were used for the power analysis. The significance level of 0.05 is generally accepted in social and behavioural science, according to Hair et al. (2010), while a power level of 80 percent is adequate in social science research (Cohen, 1988; Hair et al., 2017; Uttley, 2019). Therefore, the minimum sample size was 77.

A personally-administered questionnaire was deployed for data collection because it provided the researcher with the opportunity to briefly introduce the research topic, motivate respondents to offer true answers, and enable respondents to clarify doubts on questions immediately (Bougie & Sekaran, 2019). Prior to data collection, written permission from the palm oil mill management was obtained ahead and participants were assured that the information collected was anonymous and would remain confidential.

Survey questionnaire

The survey questionnaire was self-developed for the food safety knowledge and maintenance programme after a thorough literature review to ensure appropriate information was gathered that was relevant to the scope of this study. Meanwhile, for training effectiveness, the questionnaire was adapted from De Freitas and Stedefeldt (2022). The existing questionnaires on food safety knowledge used by Halim-Lim et al. (2023), Al-Kandari et al. (2019), Woh et al. (2016), and food safety practice by Tamiru et al. (2022) and Isoni Auad et al. (2019) deployed knowledge, attitude, and practice (KAP) questionnaires based on WHO guidelines for five keys to safer food. However, the items in existing KAP questionnaires are relevant in assessing foodborne illness caused by biological hazards, hence inappropriate for MOH since it is a chemical hazard.

Exploratory factor analysis (EFA) was carried out to examine the underlying factor structure and improve the pool of items according to Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy with value ≥0.70 (Hoelzle & Meyer, 2013; Lloret et al., 2017), statistically significant Bartlett's test of sphericity (Watkins, 2018) and item loadings greater than 0.55 (Kaiser & Rice, 1974) were also applied.

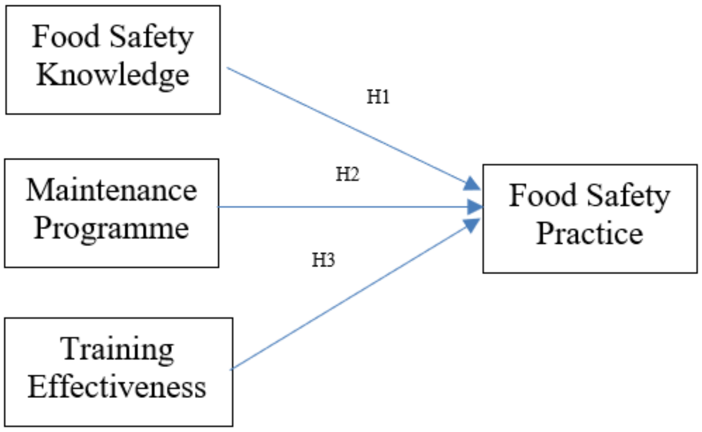
Data collection was carried out using the final survey questionnaire consisting of six parts. The first part requests participants' demographic information on gender, age, nationality, educational level, and number of employment years in the current company. The following parts including fifth section are questions on food safety knowledge (8 items), training effectiveness (8 items), maintenance programme (5 items), and food safety practice (9 items). The sixth part asks questions about whether participants attended good milling practice training and the frequency of training if they did. In this last part, participants were asked to answer questions on cognitive rigidity (3 items) adopted from Oreg (2003). Cognitive rigidity is a theoretically unrelated marker variable (MV) used to detect potential common method variance (Podsakoff et al., 2003; Simmering et al., 2015) included in this survey since data were collected from a single source (Lindell & Whitney, 2001).

Each item was assessed using a five-point Likert scale to determine agreement levels, except for food safety practices, which were evaluated using a seven-point Likert scale (Vagias, 2006).

Data Analysis Technique

Descriptive statistics were utilised to analyse participant demographic characteristics using SPSS Version 29. Meanwhile, predictive-causal research design was applied to analyse the hypothesised relationship. The current research employed partial least square structural equation modeling (PLS-SEM) to evaluate the model's parameters due to its inclusion of model development and prediction (Urbach & Ahleman, 2010). Prior to analysis, the multivariate skewness and kurtosis of the data were evaluated to determine if the data were multivariate normal, as recommended by Hair et al. (2022). Common method variance was evaluated based on R2 (<10%) and significant path changes (t-value) between the baseline and method factor models. The PLS-SEM assessment includes measurement model assessment and structural model estimation using SmartPLS version 4.0.9.9 (Ringle et al., 2022). In measurement model assessment, instrument validity and reliability were tested based on the guidelines of Hair et al. (2022) and Ramayah et al. (2018). The analysis of the structural model of the hypothesized relationships done as recommended by Becker et al. (2023), with path coefficients, standard errors, t-values, and p-values were recorded utilising a 10,000-sample resample bootstrapping method (Ramayah et al., 2018). As suggested by Hahn and Ang (2017), the significance of hypotheses was assessed using p-values, confidence intervals (CI), and effect sizes (f2),. The model's predictive relevance was confirmed at the last step. The proposed framework in this study is shown in Figure 3.1.

Figure 3.1: Proposed Framework.



Results

Demographic Characteristics

The demographic results collected from 100 food handlers presented in Table 4.1 below depict that the most common age group (45%) of the food handlers at POM are between 31 and 40 years old, while 72% are Malaysians and the remaining are foreign workers (28%). The majority (38%) of the food handlers obtained secondary school (SPM/Grade 9-10) educational levels, while 18% of the respondents do not have formal education. Most of the food handlers (45%) have 1 to 5 years of employment in the current POM. Among these respondents, mostly (79%) were not trained on good milling practices, while others (21%) trained, and the majority (11%) had trained less than once per year.

Table 4.1: Respondents' Demographic Characteristics.

Demographic characteristics	Categories	Frequency	Percent
Age	18-30	33	33.0
	31-40	45	45.0
	41-50	14	14.0
	>50	8	8.0
Nationality	Malaysian	72	72.0
	Non-Malaysian	28	28.0
Education	No formal education	18	18.0
	Primary/Grade 1-5	14	14.0
	SRP/PMR/Grade 6-8	16	16.0
	SPM/Grade 9-10	38	38.0
	STPM/Matriculation/Diploma	14	14.0
Years of employment at POM	1-5 years	45	45
	6-10 years	22	22
	11-15 years	13	13
	16-20 years	5	5
	> 20 years	15	15
Good Milling Practice Training	Yes	21	21.0
	No	79	79.0
Training Frequency	Never	79	79.0
	Less than once per year	11	11.0
	Once per year	5	5.0
	6 months once	3	3.0
	More than 6 months once	2	2.0

Multivariate Skewness and Kurtosis

Data assumptions were assessed based on Mardia's multivariate skewness and kurtosis evaluation. Based on the Kline (2016) guideline, multivariate skewness ≤ ± 3.0 and multivariate kurtosis ≤ ± 20.0 to ascertain data are multivariate normal. The result indicates the data were not multivariate normal, with multivariate skewness $\beta = 4.843$ and kurtosis $\beta = 26.070$.

Common Method Variance

The R-square (R2) and significant path (t-value) of the baseline model for endogenous constructs with and without MV depict changes in R2 of less than 10%, while the t-value remains significant compared to the method factor model (see Table 4.2). Therefore, it is concluded that the data did not show common method variance problem.

Table 4.2: Common Method Variance Test Result with Marker Variable.

Construct	R^2 without MV	R^2 with MV	t-value without MV	t-value with MV
Food safety practice	0.335	0.410	/	/
Maintenance programme	/	/	2.655	2.627
Food safety knowledge	/	/	1.279	1.507
Training effectiveness	/	/	2.632	2.619

Reflective Measurement Model Assessment

In the measurement model, first convergent validity was analysed based on outer loading, average variance extracted, and composite reliability (CR). All the items (see Table 4.3) met the cut-off value with outer loading ≥ 0.5, AVE ≥ 0.5, and CR ≥ 0.7, with the exception of item TE2 under the construct training effectiveness, which was deleted due to low loading (0.376).

Table 4.3: Measurement Model.

Item/Construct	Outer loadings	CR	AVE
FSK1 <- Food safety knowledge	0.811	0.906	0.546
FSK2 <- Food safety knowledge	0.783		
FSK3 <- Food safety knowledge	0.770		
FSK4 <- Food safety knowledge	0.725		
FSK5 <- Food safety knowledge	0.678		
FSK6 <- Food safety knowledge	0.763		
FSK7 <- Food safety knowledge	0.707		
FSK8 <- Food safety knowledge	0.663		
FSP1 <- Food safety practice	0.715	0.902	0.508
FSP2 <- Food safety practice	0.598		
FSP3 <- Food safety practice	0.737		
FSP4 <- Food safety practice	0.764		
FSP5 <- Food safety practice	0.769		
FSP6 <- Food safety practice	0.765		
FSP7 <- Food safety practice	0.719		
FSP8 <- Food safety practice	0.649		
FSP9 <- Food safety practice	0.681		
MP1 <- Maintenance programme	0.630	0.906	0.662
MP2 <- Maintenance programme	0.917		
MP3 <- Maintenance programme	0.875		
MP4 <- Maintenance programme	0.810		
MP5 <- Maintenance programme	0.808		
TE1 <- Training effectiveness	0.775	0.936	0.679
TE3 <- Training effectiveness	0.815		
TE4 <- Training effectiveness	0.723		
TE5 <- Training effectiveness	0.898		
TE6 <- Training effectiveness	0.782		
TE7 <- Training effectiveness	0.856		
TE8 <- Training effectiveness	0.904		

Note: Item TE2 were deleted due to low loading.

Discriminant validity was assessed in the next step based on the heterotrait-monotrait ratio of correlations (HTMT) criterion as recommended by Henseler et al. (2015) and updated by Franke and Sarstedt (2019). According to the criterion, the HTMT value needs to be ≤ 0.85 for the stricter criterion and ≤ 0.90 for the moderately lenient criterion. Table 4.4 shows the HTMT value was less than the stricter criterion; hence, it is concluded that discriminant validity had been established between reflectively measured constructs. Both validity tests had shown the measurement items were valid and reliable.

Table 4.4: Discriminant Validity (HTMT).

Constructs	1	2	3	4
1. Food safety knowledge				
2. Food safety practice	0.432			
3. Maintenance programme	0.320	0.451		
4. Training effectiveness	0.602	0.522	0.319	

Structural Model Assessment

The findings of the structural model assessment are presented in Table 4.5. First, the effect of three predictors on an endogenous latent variable, food safety practices, was tested. As the R2 was 0.335, this indicates that the three predictors collectively accounted for 33.5% of the variance in food safety practice. Chin (1998) characterised an R2 value of 0.33 as possessing explanatory power at a moderate level. Maintenance programme (β= 0.262, p< 0.05) and training effectiveness (β=0.333, p<0.05) were significant and positively related to food safety practice, supporting H2 and H3. Meanwhile, for food safety knowledge (β=0.156, p>0.05), the CI's were negative and positive, thus H1 was not supported. Based on Cohen's (1988) benchmark on effect size, whereby f2 = 0.02 with a small effect, f2 = 0.15 with a medium effect, and f2 = 0.35 with a large effect, the analysis result explained that both exogenous latent variables, maintenance programmes (f2 = 0.092) and training effectiveness (f2 = 0.113) have a small effect size on food safety practices.

Table 4.5: Structural Model and Hypotheses Test Results.

Hypotheses	Relationship	Std beta	SD	t-value	p-value	PCI LL	PCI UL	f^2
H1	FSK → FSP	0.156	0.122	1.279	0.101	-0.058	0.341	0.025
H2	MP → FSP	0.262	0.099	2.655	0.004	0.09	0.416	0.092
H3	TE → FSP	0.333	0.126	2.632	0.004	0.124	0.535	0.113

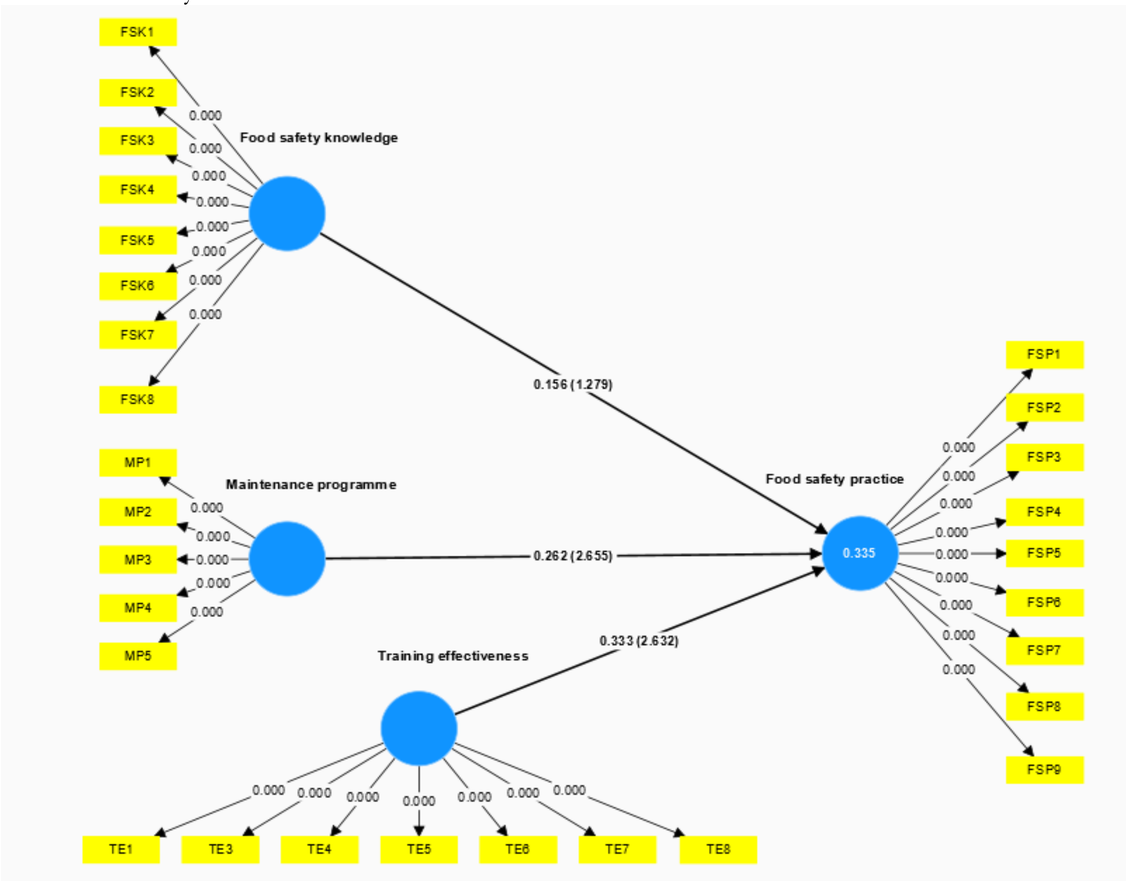
Note: FSK: food safety knowledge; MP: maintenance programme; TE: training effectiveness; FSP: food safety practice; PCI LL: percentile confidence interval lower limit; PCI UL: percentile confidence interval upper limit.

Furthermore, Shmueli et al. (2019) proposed PLS-predict to assess the model's predictive relevance. This assessment utilises a hold-out data-based procedure to produce prediction at item-level or construct-level based on PLS-predict with a 10-fold method. It is utilised to determine PLS path model estimations' predictive quality. As suggested by Shmueli et al. (2019), if the difference for all the items between PLS and the linear model (LM) is lower, it has strong predictive power. This could be explained that, when the negative difference is majority strong predictive power is confirmed, if the difference is higher for all items, it does not confirm predictive relevance. On the other hand, if the majority difference is lower than moderate predictive power, and finally if the difference is a minority, it suggests that the model possesses low predictive power. Based on the analysis, the PLS-LM difference for most of the items, with the exception of FSP6, was lower (see table 4.6), thus the model has strong predictive power. Figure 4.1 illustrates the PLS-SEM full model.

Table 4.6: PLS-Predict Result.

Item	Q^2_predict	PLS-SEM_RMSE	LM_RMSE	PL-LM_RMSE
FSP1	0.167	1.576	1.783	-0.207
FSP2	0.016	1.641	1.869	-0.228
FSP3	0.155	1.601	1.885	-0.284
FSP4	0.09	1.481	1.687	-0.206
FSP5	0.129	1.68	1.93	-0.25
FSP6	0.17	1.852	1.758	0.094
FSP7	0.141	1.57	1.721	-0.151
FSP8	0.036	1.693	1.94	-0.247
FSP9	0.182	1.562	1.672	-0.11

Figure 4.1: The Pls-Sem of Food Safety Knowledge, Maintenance Programme, Training Effectiveness, And Food Safety Practices of Pom's Food Handlers.



Discussion and Conclusion

The objective of this study was to assess the extent to which food safety knowledge, maintenance programmes, and training effectiveness has significantly and positively influenced the adherence to food safety practices by food handlers in POM, according to the three hypothesised relationships.

The analysis results showed that food safety knowledge does not have a significant impact on food safety practices. These findings contradict the results reported by Tamiru et al. (2022) and Isoni Auad et al. (2019), who found that food handlers with limited knowledge of food safety tend to engage in inadequate food safety practices. Although past literature (Al-Kandari et al., 2019; Alqurashi et al., 2019; Asmawi et al., 2018; Souza et al., 2018) shows food safety knowledge has a significant impact on food safety practices, other scholars (Reboucasetal, 2017; Putri & Susanna, 2021) argue knowledge on food safety does not favourably translate into desired food safety practices. Previous studies investigated food safety knowledge and practices on personnel hygiene, cross- contamination, time, and temperature elements in food sectors that handle food products that are highly susceptible to foodborne illness due to biological hazard contamination. As such, any malpractices resulting from a lack of knowledge will have an immediate impact. However, in this study, food safety knowledge on MOH awareness and contamination sources, as well as food safety practices on cleaning practices and vehicle hygiene, were assessed since these elements were related to MOH contamination. In addition to this, the population in this study was food handlers working in POM, compared to past studies with different populations such as caterers, students, canteen operators, and butchers. Moreover, the majority of the food handlers did not follow good milling practices that could influence the results for the said variables. Hence, the lack of significance in the relationship between food safety knowledge and practices of POM food handlers can be attributed to variations in the study's context, population setting, and appropriate milling practice training.

In relation to maintenance programme, it exhibited significant and positive relationship with food safety practices. This result signifies that having good maintenance programmes is crucial in guiding safe food practices that minimise MOH contamination risk arising from improper maintenance activities. Although these variables are less investigated in other studies within the food safety context, the analysis outcomes support the findings by Grob (2018) and Bevan et al. (2020), who asserted improper lubrication activity, which is part of a good maintenance programme, as the potential source of MOH contamination in edible oil processing.

Meanwhile, training effectiveness revealed a significant and positive impact on food safety practices. This result explains why effective food safety training is central to nurturing food handlers' food safety practices. While previous literature has recognised the importance of food safety training in promoting safe food practices, the findings of this study indicated that simply emphasizing training is not enough. Instead, organisations should ensure that the training provided to food handlers is both well-designed and effectively delivered. The outcome of this analysis result also supports the idea that safe food practices begin with effective training (Reynolds & Dolasinski, 2019).

In conclusion, this study has presented human factors that are latent in an organisation which are maintenance programmes and training effectiveness, which have significant importance for food safety practices that lead to MOH contamination in palm oil processing. In this aspect, it is imperative for POM management to attentively review the existing maintenance programmes within the factory, considering their impact on inadequate food safety practices that lead to MOH contamination. Additionally, the study also provides insights that if GMP compliances within the maintenance programme, especially on lubrication activities, are well managed, this could alleviate the investment in high-cost lubricants or greases since the key point is that managing preventive measures eventually minimises the risk of MOH contamination. Aside from this, training effectiveness is concluded to significantly and positively impact food safety practices; thus, POM management needs to assess the current state of the art in providing training in terms of training method and training content. Since the food handlers are inclusive of foreign workers, the training provided must be able to be translated into safe food practices. The analysis outcome confirmed that the majority of POM's food handlers were not provided with good milling practice training based on the MPOB code of practice; indeed, the COP has outlined the safe practices that prevent MOH occurrence during palm oil processing.

Limitations of the Research

The present study has a few limitations. Firstly, the analysis outcome in this study was derived from food handlers working in a single POM since other POM managements whom the researcher contacted did not respond to participation in the survey research. Furthermore, this study did not investigate other aspects that could potentially be linked to the lack of substantial correlation between food safety knowledge and practice. Therefore, future studies could explore other variables that influence the relationship between the hypothesised variables. Thirdly, the maintenance programme in this study analysed the elements related to maintenance procedures and hygienic maintenance practices; however, the competency of maintenance personnel has equal importance in influencing food safety practices, which was not investigated in this study.

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