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Consumer Perception Versus Scientific Evidence of Farmed and Wild Fish: Insights from Malaysia

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Abstract— Understanding consumer perceptions is crucial for shaping market demand, building consumer confidence, and promoting sustainable practices in the aquaculture sector. The main goal of this study is to examine consumers' perceptions of farmed and wild fish on various attributes, aiming to identify any discrepancies between consumer perception and scientific facts. Using random purposive sampling, a survey was conducted with 250 consumers in selected Malaysian populations recruited via street-intercept interviews. The findings reveal that the debate between consuming farmed fish and wild fish lacks a clear answer, with consumer perceptions, especially regarding freshness and sensory characteristics, often differing from scientific evidence. While fish farming offers advantages in quality control and post-mortem biochemistry, the nutritional composition of fish can vary based on farming conditions. To ensure the success of the aquaculture industry in Malaysia, there is a need to enhance practices, raise awareness among aquaculturists, and educate consumers about the benefits of well-managed aquaculture. By adopting a multidisciplinary approach and addressing the crucial nexus between consumer perceptions and sustainable aquaculture, this study makes a valuable and timely contribution to the ongoing discourse in the aquaculture sector. It offers insights that can inform strategies for promoting responsible seafood consumption and advancing the sustainability agenda in Malaysia's aquaculture industry.

***Keywords*— Consumer perception, Beliefs, Safety, Farmed fish, Wild fish, Aquaculture.**

INTRODUCTION

In recent decades, the global consumption of fish has significantly increased, driven by its perceived health benefits, a growing global population, and improved living standards (Carlucci et al., 2015). However, this heightened demand has resulted in overfishing and depletion of wild fish stocks (FAO, 2016). Like many other regions, Malaysia heavily relies on wild-caught fish obtained through intensive sourcing methods (Goh et al., 2021), raising sustainability concerns. To address this, there is an urgent need to expand the aquaculture industry, as fish serves as the primary source of animal protein in Malaysia (Goh et al., 2021).

Despite the potential of aquaculture, its development in Malaysia faces various challenges, including technical and adaptive obstacles. Moreover, consumer perceptions towards fish from aquaculture that lack official acknowledgment and research have hindered the industry's full potential. The lack of sustainability literacy among Malaysians (Goh et al., 2023) further complicates the issue, and there is a need to address any negative perceptions towards farmed fish and determine if they are scientifically valid. To address this, consumer-focused approaches are essential to influence sustainable consumption patterns and promote acceptance of aquaculture products.

Consumer studies in other markets, such as the United States of America and European Union, have focused on attitudes towards aquaculture products (Verbeke et al., 2005; Verbeke and Vackier 2005; Verbeke et al., 2007; Vanhonacker et al., 2011; Hall and Amberg, 2013; Schlag and Ystgaard, 2013; Claret et al., 2014). These studies have confirmed that consumers perceive fish as a healthy part of their diet, despite a gap between scientific evidence and consumer perceptions regarding the health character and nutritional value of fish (Verbeke et al., 2007). Knowledge about fish and aquaculture practices is essential for consumers to make informed choices between wild-caught and farmed fish, particularly concerning concerns about potential adverse effects of poor aquaculture practices.

As aquaculture evolves, discussions on health, safety, and sustainability of farmed versus wild fish will gain traction, similar to trends in developed countries (Verbeke et al., 2007). Understanding and addressing consumer perceptions are crucial for industry growth, promoting sustainable practices, and shaping effective policies and regulations. Aligning strategies with consumer expectations builds trust and acceptance of aquaculture products. This understanding also helps identify consumer preferences for sustainable and environmentally friendly fish farming methods, conserving resources and minimizing environmental impact. Policymakers can benefit from insights into consumer perceptions while developing regulations for safe, quality, and sustainable farmed fish.

Understanding consumer perceptions towards aquaculture products is crucial due to the significance of consumer attitudes. The main goal of the current research is to investigate how consumers perceive farmed and wild fish differently, specifically focusing on identifying disparities between consumer perception and scientific facts. The survey was conducted in selected areas within the Klang Valley, Malaysia's most densely populated region, comprising urban, rural, and coastal towns, representing all major ethnic groups. Samples from the urban population were collected in Kuala Lumpur, from the coastal population in Kuala Selangor (approximately 60 km from central Kuala Lumpur), and from the rural population in Hulu Selangor (about 50 km from central Kuala Lumpur).

METHODS

A. Study Design

This paper is part of a larger project that included six main components: (i) frequency of fish consumption, (ii) factors influencing consumption behaviour, (iii) motivation for consuming fish, (iv) barriers to fish consumption, (v) preferences and perceptions of farmed and wild fish, and (vi) general consumer knowledge about fish. In this paper, we specifically focus on components (i) and (v) of the questionnaire. The overall methodology and results related to the other components have been previously reported in another paper by the authors (Goh et al., 2023). Briefly, the survey data was gathered using a questionnaire over a period of five months, specifically from October 2015 to February 2016. Subjects were randomly recruited through street-intercept in selected areas within Klang Valley and Selangor, namely shopping streets, supermarkets, and wet markets. Upon approaching the subjects, they were screened and provided with information about the study. Verbal consent was obtained prior to conducting the interviews using the questionnaire. The study included adult individuals of both genders residing in Klang Valley and Selangor, Malaysia. Purposive sampling was used to select the participants, and the inclusion criteria were: (1) Malaysian of Malay, Chinese, or Indian ethnicities; (2) aged between 18 and 60 years; (3) in good health with no known illnesses; and (4) capable of providing informed consent. All respondents needed to be the primary person responsible for food purchases within their household, while individuals who recently changed their dietary patterns or followed special diets, such as vegetarianism, were excluded from the study.

B. Questionnaire Design and Data Collection

Component (i) Frequency of (farmed) fish consumption: Assessing the frequency of farmed fish consumption posed challenges due to the absence of a formal consensus. To tackle this, a fish availability survey was conducted, documenting the names of fish species sold at various grocers, markets, and restaurants. This comprehensive list of commonly available and consumed fish species was generated (see Appendix 1). In order to identify predominantly farmed species from the list, an analysis of data from capture fishery landing and seedling hatcheries was carried out. The selected list of farmed fish was further validated through consultations with aquaculture consultants, fish suppliers, and fishmongers. A 6-point frequency scale was assigned to the identified farmed fish, ranging from "seldom/never" to "more than 5 times a week". The reported consumption frequencies for farmed fish were tallied, and participants who consumed farmed fish more than 3 times a week were categorized as 'heavy users'. 'Moderate users' were defined as those who consumed farmed fish less than twice a week but at least once a month, while 'light users' referred to individuals who consumed farmed fish less than once a month.

Component (v) Consumer preference and perception of farmed and wild fish: Both preference and perception are subjective and vary among individuals. Preferences can be shaped by perceptions, such as when an individual, perceiving a food as unhealthy, develops a preference for healthier alternatives (Font-i-Furnols & Guerrero, 2014). Preference is centered on liking or choosing, while perception is focused on interpreting sensory information (Font-i-Furnols & Guerrero, 2014). Initially, respondents were asked about their specific preferences regarding wild or farmed fish, as well as whether they had knowingly purchased farmed fish in the past. Following that, an assessment was conducted to determine the perceptions of farmed and wild fish across 12 different attributes. These attributes included freshness, quality, smell, taste, texture, availability throughout the year, price stability throughout the year, being considered "premium", value for money, health benefits, contaminant content, and sustainability. The selection of these attributes was based on relevant literature (Verkebe et al., 2007; Davidson et al., 2012; Vanhonacker et al., 2013; Katrin & Ystgaard. 2013; Can et al., 2015). Respondents were required to indicate whether they believed fish of wild or farmed origin was superior in each of these attributes. To allow for more nuanced responses and to avoid any bias from forced choices, two additional response categories were included: "no difference" and "don't know". This helped to better segregate the respondents' perspectives on the matter.

C. Statistical Analysis

Data were analysed using SPSS 22.0 (SPSS Inc., Chicago, IL, USA). Non-parametric bivariate analyses through correlation and comparison of mean scores, i.e. Wilcoxon–Mann–Whitney test and analysis of variance F-tests with Dunnett T-3 post hoc comparison of mean scores, were used to detect differences in frequency of consumption. To examine the relationships between perceptions of farmed and wild fish among different sociodemographic and behavioural consumer groups, Pearson's chi-squared test was employed. While numerous factors were evaluated, only those exhibiting significant differences between the categorised groups were reported. In order to determine the validity of consumers' perceptions of wild versus farmed fish, a comparison was made against relevant literature, evaluating whether these perceptions were supported or unfounded. The findings and implications of these analyses are discussed in the Discussion section of the paper.

D. Results

Sample Characteristics

Out of the 310 questionnaires collected, 76% (n=250) were considered 'complete', while the remaining 24% (n=60) were categorized as 'incomplete or unreliable'. Among the analysed questionnaires (n=250), there were 188 women (75.2%) and 62 men (24.8%), meeting the criteria that each respondent should be the primary person responsible for food purchases in their household. The sample included a diverse group of consumers with varying sociodemographic characteristics, such as education, income, and educational background (see Table 1). Fifty-four questionnaires from the 'incomplete or unreliable' category were excluded from the dataset due to containing self-contradictory responses lacking credibility.

Table 1: Consumers' characteristics (%, n=250)

Characteristics	**Proportion %**	**Total Sample (n=250)**
Gender		
Male	24.8	62
Female	75.2	188
Age (years)		
18 – 29	14.0	35
30 – 39	22.4	56
40 – 49	27.6	69
50 – 59	22.8	57
60 – 69	11.2	28
≥70	1.2	3
Geographical Location		
Urban	50.4	126
Coastal	24.8	62
Rural	24.8	62
Ethnicity		
Malay	57.6	144
Chinese	29.2	73
Indian	13.2	33
Highest Level of Education		
Primary Education	16.0	40
Secondary Education	36.4	91
Certificate/Diploma	29.6	74
Bachelor's Degree	10.8	27
Postgraduate Degree	6.0	15

The distribution of respondents across different age groups followed an approximately normal pattern. Roughly half of the respondents (50.4%) lived in urban areas, while the remaining were evenly distributed between rural (24.8%) and coastal (24.8%) areas (see Table 1). A significant majority (82.8%) of the respondents had received at least 12 years of formal education (see Table 1).

Reported Preferences of Farmed Fish and Frequency of Consumption

When respondents were asked about their preferences for the origin of fish, a significant portion of urban respondents (58.7%) indicated no special preference, while a majority of coastal (67.7%) and rural (58.1%) respondents expressed a preference for wild fish (refer to Table 2). Among the male respondents, approximately 68% preferred wild fish, whereas 55% of the female respondents had no special preference. Interestingly, a larger proportion of participants below the age of 40 showed no special preference, with 67% of those aged 18-29 and 62% of those aged 30-39 falling into this category. In contrast, the older age groups exhibited a significantly higher preference for wild fish, with 50% of participants aged 40-49 and 55% of those aged 50-59 favouring wild fish. These findings suggest that the older generation maintains a stronger attachment to the fishing heritage that was once a lifeline in Malaysia (Rusli, 2012; Chan, 2012), while the younger generation appears to be less influenced by this narrative.

When respondents were questioned about their past purchases of known farmed products, 44.6% of the total participants answered in the affirmative, with the highest prevalence observed among rural respondents (62.9%) (refer to Table 3). Notably, a significant portion of urban respondents (42.4%) indicated uncertainty regarding their past purchases of farmed fish and/or fish (refer to Table 3).

Table 2: Fish origin preference across different geographical locations

Do you prefer wild or farmed fish?	**Total (n=250) %**	**Urban (n=124) %**	**Rural (n=62) %**	**Coastal (n=62) %**
No special preference	46.0	58.7	38.7	27.4
Wild	46.4	30.2	58.1	67.7
Farmed	7.6	11.1	3.2	4.8

Table 3: Self-reported past purchase of farmed fish and/or fish across different geographical location

Have you ever purchased farmed fish?	**Total (n=250) %**	**Urban (n=124) %**	**Rural (n=62) %**	**Coastal (n=62) %**
Yes	44.6	35.2	62.9	45.2
No	29.3	22.4	29.0	43.5
Not sure/ Don't know	26.1	42.4	8.1	11.3

Due to the general lack of knowledge among Malaysian consumers regarding the origin of fish (Goh, 2018), a predetermined list of farmed fish species was utilized to evaluate the frequency of consumption of farmed fish. The findings revealed that 62% (n=155) of the total respondents consumed at least one species of the listed farmed fish on a weekly basis, with the highest prevalence observed in rural areas and the lowest in urban areas. One striking discovery in this study was that out of the total 73 respondents who claimed to be non-consumers of farmed fish, 63 individuals paradoxically reported regularly purchasing Vannamei prawns, which are predominantly farmed, at least once a month. Notably, a significant majority (81.0%) of these respondents who unknowingly purchased farmed prawns were urban residents. This finding further confirms the lack of awareness among Malaysian consumers regarding the origin of fish.

General Perceptions of Farmed versus Wild Fish

The divergent perceptions that consumers held regarding various attributes of farmed and wild fish are presented in Table 4. Notably, individuals who considered farmed fish to be superior in most attributes consumed significantly greater amounts of farmed fish compared to those who held a different viewpoint.

Table 4: Prevalence of consumers with different perceptions towards farmed versus wild fish

Sensory Attributes	**Responses (n=250)**			
	Farmed is better %	**Wild is better %**	**No difference %**	**Don't know/ understand %**
Freshness	13.7	53.0	18.9	0.0
Quality	13.7	57.8	12.4	16.1
Smell	12.5	56.5	16.1	14.9
Taste	10.4	63.1	12.9	13.7
Texture	10.5	57.5	15.4	16.6
Non-sensory Attributes	**Responses (n=250)**			
	Farmed is better %	**Wild is better %**	**No difference %**	**Don't know/ understand %**
Availability throughout the year	31.6	19.8	16.6	32.0
Price stability throughout the year	30.9	15.0	21.1	32.9
"High-class" food	11.3	49.4	18.2	21.1
Value for money	16.9	39.5	23.4	20.2
Health benefits	8.9	54.7	19.4	17.0
Contaminant content	21.0	30.6	13.7	34.7
Sustainability	16.3	23.3	15.1	45.3

In terms of taste, texture, and freshness, wild fish were considered to be superior by a majority of respondents, with 63.1% perceiving wild fish as having better taste, 57.5% associating wild fish with superior texture, and 53% attributing higher freshness to wild fish. Additionally, when compared to other consumer groups, a significantly greater number of coastal consumers ($p<0.05$) believed that wild fish surpassed farmed fish in terms of taste and freshness. Approximately half of the consumers regarded wild fish as a "high-class food," and once again, a significantly higher proportion of coastal respondents ($p<0.05$) (75.8%) shared this perception of wild fish as a premium food. No other significant socio-demographic differences in the perception of farmed versus wild fish were observed.

While approximately one-third of consumers believed that farmed fish had better stock availability and price stability, an almost equal percentage of consumers either had no knowledge or understanding of these two attributes. Approximately half of the consumers perceived that wild fish had more health benefits compared to farmed fish. When it came to the perception of contaminant content, an equal number of consumers considered farmed fish to be more contaminated (30.6%) as those who indicated they "Don't know and/or understand" (34.7%).

E. DISCUSSIONS

The majority of consumers in the sample exhibited perceived differences between farmed and wild fish, particularly among coastal respondents. This can be attributed to the influence of geographical location, which affects the frequency and types of fish consumed, as well as the perceived disparities between farmed and wild fish. Consumers perceived farmed fish as inferior in various quality-defining aspects, including freshness, taste, texture, health benefits, and contaminant content, in comparison to their wild counterparts. Since these consumers considered health benefits and freshness as crucial factors when purchasing and consuming fish, their unfavourable perceptions of these quality-defining attributes could explain their low preference for farmed products. This finding aligns with the research of Verbeke et al. (2007), which suggests that consumers' opinions and beliefs regarding farmed fish are predominantly influenced by emotions rather than awareness and factual knowledge about aquaculture.

Consumers rely on organoleptic properties and nutritional value, along with freshness, to assess the quality of fish (Grigorakis, 2007). These characteristics are influenced by the chemical composition of the fish, which, in turn, is dependent on inherent factors such as species and sex, environmental variables like temperature and salinity, and feeding history including diet composition (Grigorakis, 1999). In Europe, extensive research has been conducted to differentiate between wild and farmed fish for the authentication of Atlantic salmon products (Aursand and Axelson, 2001; Aursand et al., 1994, 2000; Igarashi et al., 2002; Bell et al., 2001). However, it is important to note that no relevant authentication analysis has been conducted in Malaysia and the surrounding region, primarily due to the fact that the commonly consumed fish are either exclusively wild or exclusively farmed.

The subsequent subsections explore the potential variations between farmed and wild fish concerning freshness, taste, texture, health benefits, and contaminant content. Any discrepancies between consumer perceptions and scientific facts are also identified.

Is farmed fish not as fresh as the wild ones? Ensuring the freshness of captured fish is crucial, and immediate cooling and careful handling onboard are necessary to control, reduce, or retard microbial activity (Borderías et al., 2011; FAO and WHO, 2012). In the case of farmed fish, maintaining the cold chain through chill-killing methods helps preserve freshness. On the other hand, capture fisheries must ensure that fish are promptly iced at 0°C after catch to minimize spoilage. While large commercial fishing vessels are equipped with refrigeration systems, traditional fishermen often use ice boxes. However, to maintain fish freshness, some Malaysian fishers and fish vendors unfortunately resort to the careless use of formaldehyde as a preservative agent. N.V. Subbarow, the education officer of the Consumers Association of Penang, reported that fishermen on longer sea voyages of approximately 10 days may mix formalin with ice to ensure fish freshness (Tan et al., 2012).

Concerns regarding the sale and distribution of formaldehyde have been raised by Datuk Wilfred Lingham, the president of the Sabah Anglers Association, who urges authorities to strictly monitor its use (Anon., 2015). Improper use of formalin has been confirmed in two studies conducted in Malaysia, where researchers discovered unnatural levels of formalin in tested fish samples, not limited to wild fish but also purchased from fish markets (Noordiana et al., 2011; Siti Aminah et al., 2013). It is impossible to determine whether formalin was used out at sea or by vendors to help keep the fish fresh. This illicit practice of using formalin as a preservative is not limited to Malaysia but has become a global issue, as reported in various parts of the world (Chandralekha et al., 1992; Tunhun et al., 1996; Drastini and Widiasih, 2009; Tang et al., 2009; Andrews, 2013).

To maintain fish freshness, the fishing industry, both in capture fisheries and fish farming, shares common objectives. These include minimizing stress during harvest and ensuring low post-harvest temperatures. Fish farming offers advantages over capture fisheries, allowing control over pre- and post-mortem biochemistry and freshness parameters. In Southeast Asia, the predominant marine capture methods involve trawling and purse-seining, which may subject wild fish to more stress and injuries compared to farmed fish, potentially increasing spoilage rates. The unregulated use of formalin by local fishermen to preserve wild fish poses unknown health risks to consumers (Wooster et al., 2005; Hoque et al., 2016). Additionally, farmed fish can be 'harvested to order,' reducing the need for long-distance transportation and the use of preservatives, unless stored for extended periods with chemical ice. Consequently, the perception among consumers that wild fish are inherently superior in freshness lacks scientific evidence.

Is the texture of farmed fish poorer than the wild ones? The texture of fish is influenced by various factors, including species-specific characteristics and multiple contributing factors. Due to the extensive nature of this topic, only selected factors relevant to comparing wild and farmed fish are discussed. These factors can be broadly categorized as follows: 1) muscle structure of fish flesh, 2) muscle cell biology, and 3) the level of physical exercise. Comparing results from different studies on texture quality is challenging due to the inconsistent correlation between instrumental analysis of raw fish and sensory analysis of cooked fish (Andersen et al., 1997; Bjørnevik et al., 2003). Nevertheless, differences observed between fish from different systems provide insights into the overall impact of genetic makeup and life history on texture quality. However, these differences in texture may be mitigated after storage. Alasalvar et al. (2002) reported that the texture of cultured and wild sea bream decreased during storage, and the texture of both groups did not significantly differ until day 16, when the wild fish became significantly softer than the farmed fish. It is important to note that preference for fish flesh texture is a subjective opinion. Aquaculturists have an advantage over fishermen as they can manipulate various stages of rearing, feeding, and processing to produce fish with desired textural quality for consumers. Therefore, the perception among consumers that wild fish has superior texture compared to farmed fish is not supported by evidence.

Is farmed fish poorer in flavour and odour than the wild ones? Flavour plays a crucial role in consumer acceptance of fishery products, as highlighted by Haard (1992). The perception of flavour and odour is often associated with freshness, as noted by Rasmussen (2001). Therefore, it is essential to implement proper initial processing steps and subsequent storage methods for fish. The main cause of food spoilage is microbial growth and metabolism, which leads to the production of undesirable off-flavours such as amines, sulphides, alcohols, aldehydes, ketones, and organic acids (Gram and Dalgaard, 2002). For instance, bacterial reduction of trimethylamine oxide to trimethylamine results in the characteristic "fishy" odour in fish (Rasmussen, 2001). Additionally, oxidative rancidity contributes to off-flavour occurrences. When fish is inadequately stored and packaged, the highly unsaturated fatty acids present in fish can undergo oxidation upon exposure to atmospheric oxygen, leading to rancidity (Rasmussen, 2001). However, the rate of rancidity in unsaturated fatty acids can be reduced by the presence of antioxidant vitamins. To prevent lipid peroxidation and enhance product preservation, vitamin E supplements can be incorporated into artificial fish diets (Verbeke et al., 2007). Although susceptible to rancidity, unsaturated fatty acids serve as important precursors for volatile flavour compounds (Grigorakis, 2007). The distinctive aroma compounds in fresh fish, such as alcohols and carbonyls, are derived from specific polyunsaturated fatty acids and the lipoxygenase enzyme involved in hydroperoxide formation (Haard, 1992). Free amino acid content is another taste-active compound in fish, significantly impacting the taste perception in the mouth (Arechavala-Lopez et al., 2013).

According to Fuentes et al. (2010), farmed and wild fish exhibit variations in their fatty acids and free amino acids (FAAs) profiles. The volatile aroma compounds present in wild fish encompass a higher number of more delicate taste-contributing compounds. In contrast, Alasalvar et al. (2005) discovered that aldehydes, ketones, aromatics, and terpenes were more prominent in wild sea bream compared to its cultured counterpart. Wild ayu (sweetfish), as described by Suyama et al. (1985), possesses a sweet aroma resembling watermelon, which distinguishes it from cultured ayu. Josephson and Lindsay (1986) proposed that the higher content of eicosapentaenoic acid (EPA) in wild fish leads to enzymatic action on EPA, resulting in the formation of hydroperoxides that undergo chain breakage, producing these melon-like volatile compounds. On the other hand, cultured sea bass exhibits higher levels of certain FAAs associated with the characteristic flavour of fish, such as glutamic acid, aspartic acid, alanine, and glycine (Fuentes et al., 2010). These differences in fatty acids and FAAs, which contribute to the organoleptic characteristics, can lead to variations in the flavour and aroma of fish, thereby influencing consumers' perception based on their origin (farmed or wild). However, it should be noted that sensory indicators do not consistently provide a definitive basis for distinguishing between farmed and wild sea fish (Arechavala-Lopez et al., 2013). Ultimately, the selection of the best fish flavour and aroma is subjective and a matter of personal preference.

It is well established that the aroma and taste of fish can be influenced by their diet. For instance, the consumption of certain marine algae containing dimethyl-ß-propiothetin by marine fish can lead to an off-odour caused by dimethylsulfide (Ackman et al., 1966, 1968, and 1972). Similarly, cultured fish can be affected by both pleasant and unpleasant aromas present in commercial feed. There have been anecdotal reports suggesting that farmed salmon fed crustacean meal exhibit better flavour compared to fish fed solely on commercial rations (Haard, 1992). This preference may be attributed to the fish fed with crustacean meal having a more vibrant orange or salmon colour, which can influence people's perception of taste (Kalidoss Manikandan & Prabu, 2020). In contrast, the partial inclusion of soybean oil in the diet of sea bream has shown slight influences on organoleptic properties, such as a stronger smell and taste (Izquierdo et al., 2005). High levels of soybean oil in the feed of salmonid fish have been associated with the development of an off-flavour known as 'hatchery flavour' (Haard, 1992). However, in sea bass, the complete substitution of fish oil with soybean oil did not show a statistically significant effect on taste and odour (Montero et al., 2005). Additionally, crude oil and other hydrocarbon contaminants in marine waters, particularly in areas with intensive offshore oil exploitation or large oil spills, can result in off-flavours in both farmed and wild marine fish. This accumulation of water-soluble hydrocarbon compounds, particularly aromatic compounds, contributes to strong flavour characteristics (Martinsen et al., 1992).

On the contrary, the distinction between freshwater and saltwater fish appears to have a greater impact on flavour differences than whether the fish is wild or farmed. Research has indicated that the primary flavour differences exist between river-caught and sea-caught salmon, rather than between wild and farmed salmon (Farmer et al., 2000). In a sensory evaluation conducted by Flos et al. (2002), flavour differences were observed among sea bream from three different inland culture systems with varying intensities, but no differences were found between these cultured fish and their wild counterparts. These sensory disparities may be attributed to variations in the microbiological quality of water, as the aroma of fish is heavily influenced by the presence of certain organisms and algae in the aquatic environment, particularly in freshwater (Orban et al., 1997). In freshwater fish, the most common off-flavour compounds are geosmin (GSM) and 2-methylisoborneol (2-MIB), which are exclusively found in freshwater and are produced and released by cyanobacteria species into the water (Smith et al., 2008). GSM and 2-MIB are lipophilic compounds that can accumulate in the fatty tissues of fish (Robertson et al., 2006; Percival et al., 2008). It has been demonstrated that these compounds primarily enter the fish through the gills (From and Hørlyck, 1984), and their bioaccumulation leads to the presence of an undesirable, yet harmless, earthy-musty taste in exposed organisms (Robertson et al., 2006; Percival et al., 2008).

In Malaysia, tilapia and catfish are the most commonly cultured fish for local consumption, and they are predominantly freshwater species. The production of freshwater fish in the country primarily comes from mining pools and earthen ponds (DoFM, 2014). Notably, Nurul Izzah et al. (2004) discovered the presence of GSM and 2-MIB in tilapia caught from various locations such as ex-mining pools, rivers, and lakes in Selangor, Malaysia. The concentrations of these compounds varied, with higher levels found in more stagnant water bodies (Nurul Izzah et al., 2000). Integrated farm systems are commonly practiced in Malaysia, particularly among small-scale farmers and larger entities like the Federal Land Development Authority (FELDA) (FAO, 2017b). In this system, fish are cultivated alongside poultry and crop plantations, allowing nutrients from poultry waste, uneaten feed, and other organic matter to fertilize the pond water, thereby reducing the reliance on commercial fish feed (Pimolrat et al., 2015). However, proper management of water exchange and maintaining the appropriate fish-to-poultry ratios are crucial in these freshwater farms to ensure water quality. The levels of GSM and 2-MIB tend to increase when water quality deteriorates, particularly in stagnant water bodies affected by eutrophication that promotes the growth of cyanobacteria (Gutierrez et al., 2013; Pimolrat et al., 2015).

The removal of taint compounds from fish can be achieved by transferring them to water that is free of GSM and 2-MIB. However, this process is much slower compared to the rate at which these compounds are absorbed (Robertson et al., 2006). The presence of off-flavours caused by GSM and 2-MIB is a significant issue for the freshwater fish industry, as consumers strongly dislike these flavours in fish products (Robertson et al., 2006; Robin et al., 2006; Gutierrez et al., 2013). Pond-raised catfish, for example, can exhibit off-flavours described as sewage, stale, muddy-musty, rancid, metallic, mouldy, weedy, and petroleum (Johnsen et al., 1987). The problem of earthy-musty taints in freshwater fish, whether wild or farmed, is a global concern. It has been documented in various commercially important freshwater species such as tilapia, catfish, trout, salmon, and barramundi in different regions, including North America (Dionigi et al., 2000; Zimba and Grimm, 2003; Hurlburt et al., 2009), Europe (Robertson et al., 2006; Robin et al., 2006), Asia (Gutierrez et al., 2013; Pimolrat et al., 2015), and Australasia (Jones et al., 2013; Hathurusingha et al., 2016).

The types of farmed fish available locally in Malaysia is primarily limited to freshwater species, which are generally less popular than wild-caught marine fish (Goh et al., 2021). This lower consumer preference for farmed freshwater fish may be attributed to their distinct sensory characteristics, which differ from marine fish. In 2001, Jamilah et al. conducted a study to investigate the flavour profiles of common freshwater and marine fish in Malaysia. Trained panellists assessed the aroma, flavour, and aftertaste of tilapia, Indian mackerel, small tuna, and catfish. The earthy flavour characteristic was identified in both tilapia and catfish, but not in any of the marine fish. In fact, it was the dominant flavour detected in tilapia and catfish. On the other hand, fish oil aroma was identified as the strongest characteristic in Indian mackerel and small tuna. Therefore, it is hypothesized that Malaysian consumers have a strong preference for the fish oil aroma, and since tilapia and catfish are primarily farmed, the perception of inferior flavour and aroma in farmed fish arises.

Due to the negative reputation associated with the consumption of inferiorly farmed freshwater fish like tilapia and catfish, it is understandable that Malaysian consumers perceive wild fish to have superior flavour and odour. However, what consumers may not realize is that many factors influencing the typical aroma of fish, such as the content of n-3 polyunsaturated fatty acids (PUFA) in the muscle, dietary patterns, and water quality, can be manipulated by farmers and fish feed producers. These factors are, however, beyond the control of wild fish.

Is farmed fish less nutritious compared to the wild ones? Fish is a highly nutritious food, providing a diverse range of essential nutrients for human health. In an advisory note prepared by Torry Research Station, the structure and main components of fish muscle in commercial fish were described and explained (Murray and Burt, 2001). It was explained that the protein content in fish generally falls within the range of 15% to 20%, which is comparable to meat. Additionally, often overlooked parts of the fish, such as the head, viscera, and backbones, constitute a significant portion (30-70%) of the fish and are particularly rich in micronutrients like iodine, vitamin D, and calcium (Murray and Burt, 2001). This highlights the importance of consuming these parts, as they provide essential micronutrients that may not be obtained from consuming larger fish. Considering all fish species, the fat content can vary significantly compared to the water, protein, or mineral content. While the ratio of the highest to the lowest protein or water content is no more than three to one, the ratio for fat content can be more than 300 to one (Murray and Burt, 2001).

Fish stands out among other animal proteins due to its highly beneficial fatty acid profile, which contributes to its nutritional advantages. Long chain n-3 polyunsaturated fatty acids (PUFAs), such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), have gained increasing attention for their significance in human nutrition. These fatty acids are abundantly present in fish. Ensuring an adequate intake of n-3 PUFAs is important for maintaining human health and preventing coronary heart diseases, as emphasized by the World Health Organization (WHO, 2008). While selected vegetable oils like olive, canola, and soybean oils also serve as sources of n-3 PUFAs, their usage is less common in Malaysia (NCFFN, 2005). Palm oil, being the primary cooking oil in Malaysia, dominates the dietary oil consumption, with an average intake of 6.6kg per capita per year or 17.8g per capita per day (FAO, 2011). Palm oil is high in saturated fat, with a content of 50%. Another significant source of saturated fat (92%) in the Malaysian diet is coconut oil, often used in meal preparation due to the use of coconut milk. Therefore, fish remains the primary source of n-3 PUFAs in the Malaysian diet. In fact, respondents in the current study exhibited limited knowledge about fish, but were aware that fish is a source of n-3 PUFAs, commonly referred to as omega-3 locally (Goh et al., 2023).

The composition of polyunsaturated fatty acids (PUFAs) varies significantly among different fish species, whether they are from freshwater or marine environments. Numerous factors influence the PUFA composition, including temperature, salinity, season, size, age, habitat, life stage, and the type and availability of food sources (Hossain, 2011). In the case of wild fish, the availability and abundance of food in their natural habitat fluctuate annually, seasonally, and geographically, which in turn affects the overall fat content and composition in fish tissues. The values provided in nutrient databases represent averages and not absolute amounts. If a few samples of wild fish were taken, it is highly likely that the total fat level and the percentage of n-3 PUFAs in the muscle tissue would differ from the official values (Hardy, 2003). In favourable habitat conditions, wild marine fish, particularly carnivorous species, have a natural diet that is rich in highly unsaturated n-3 PUFAs. These fatty acids, which accumulate in the marine food chain, depend on primary producers such as marine phytoplankton (Ruiz-Lopez et al., 2012). Primary producers have the capability to synthesize long-chain PUFAs, including docosahexaenoic acid (DHA), from short-chain n-3 alpha-linolenic acid (ALA) and short-chain n-6 linoleic acid (LA) through a series of desaturation and elongation reactions. Additionally, they can directly synthesize DHA from docosapentaenoic acid (DPA) (Strobel et al., 2012).

The fatty acid composition of freshwater and marine fish differ due to variations in their respective food systems. The marine food chain is abundant in long-chain n-3 fatty acids such as eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), while the freshwater food system contains higher levels of linoleic acid (LA) and alpha-linolenic acid (ALA) (Tocher, 2010). Freshwater fish have higher concentrations of n-6 fatty acids and short-chain n-3 PUFAs compared to marine fish, which have higher levels of long-chain n-3 PUFAs (Hossain, 2011). Marine fish typically require long-chain n-3 highly unsaturated fatty acids (HUFA) such as EPA and DHA for optimal growth and health (Craig et al., 2017). On the other hand, freshwater fish do not need these long-chain HUFA but instead rely on LA, which they cannot produce internally and must obtain from their diet (Craig et al., 2017). Some freshwater fish have the ability to convert LA into longer-chain n-3 HUFA, including EPA and DHA, through specific enzyme systems. These long-chain n-3 HUFA are crucial for other metabolic functions and serve as components of cellular membranes (Craig et al., 2017). Essentially, freshwater fish can transform food sources with limited nutritional value into highly nutritious food. In contrast, marine fish lack these elongation and desaturation enzyme systems and therefore require dietary intake of long-chain n-3 HUFA (Craig et al., 2017).

In contrast, farmed fish have a consistent intake of nutrient-dense feed throughout the year, leading to the accumulation of substantial lipid reserves (Verbeke et al., 2007). The lipid composition of farmed fish is specific to each species and heavily influenced by the composition of their feed. Ultimately, the levels of long-chain n-3 polyunsaturated fatty acids (PUFAs) in the fish flesh are determined by the levels present in the feed (Sprague et al., 2016). Differences in total fat content and fatty acid composition between wild and farmed fish can arise due to variations in feed (natural versus artificial), seasonal fluctuations, environmental temperature, and geographical location (Hunter et al., 2001). Aquaculture production systems can be categorized as either extensive systems, which involve low animal density relative to water volume, or intensive systems, where higher animal density is employed (Creti et al., 2010). In intensive systems, fish are bred in tanks and fed with formulated feeds, while in extensive systems, fish grow in lagoons or brackish waters and rely on natural food sources (Creti et al., 2010). When the natural diet is supplemented with specialized feed, the system is referred to as semi-intensive (Creti et al., 2010). A study conducted by Karapanagiotidis et al. (2006) in Thailand, a major tilapia producer, demonstrated significant variations in the PUFA content of farmed and wild tilapia based on the aquaculture production systems. Wild fish that grew under extensive conditions exhibited a more desirable fatty acid profile for human consumption, characterized by higher proportions of n-3 PUFAs (18:3n-3, 20:5n-3, and 22:6n-3) and higher n-3/n-6 PUFA ratios (Karapanagiotidis et al., 2006).

Consumers commonly hold the belief that farmed fish are of lower quality and nutritional value compared to wild fish (Sprague et al., 2016). Extensive research has been conducted in Western countries to examine whether farmed fish can match the omega-3 fatty acid content of their wild counterparts (Nettleton and Exler, 1992; Haard, 1992; Serot et al., 1998; Alasalvar et al., 2002; Olsson et al., 2003; Cahu et al., 2004; EFSA 2005; Hamilton et al., 2005; Gonzalez et al.; 2006; Álvarez et al., 2009; Bhouri et al.; 2010; Hossain et al., 2011; Henriques et al., 2014; Lövkvist, 2014; USDA, 2015; Sprague et al., 2016). However, these studies primarily focused on the most popular farmed species in the region, such as salmon, seabass, seabream, and trout. The findings indicated that while farmed fish generally have higher total lipid content, the levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) relative to their total fatty acid content are typically lower compared to wild fish. Nevertheless, due to the higher total lipid content, the PUFA content per portion of farmed fish is ultimately equal to, if not higher than, that of wild fish (ESFA, 2005). Unfortunately, the presentation of fatty acid profiles as a percentage of total lipid often leads to misconceptions regarding the perceived higher nutritional content of long-chain n-3 PUFAs in wild fish compared to farmed fish (Sprague et al., 2016). Additionally, the cholesterol and protein levels in farmed fish are similar to those in wild fish (Cahu et al., 2004). Consequently, it can be concluded that the nutritional value of farmed fish in Western countries is at least as beneficial as that of their wild counterparts, particularly in terms of preventing coronary heart diseases.

Conducting comparative research on the omega-3 content of wild fish and their farmed counterparts is impractical in the Malaysian context. This is due to the fact that commonly consumed marine fish in Malaysia are exclusively wild, while commonly farmed species are usually freshwater fish. It would be unfair to make a general comparison because it is well-known that freshwater fish, regardless of whether they are farmed or not, tend to have lower levels of omega-3 fatty acids.

A review of the Food Composition Database and available literature on the fatty acid composition of selected fish in Malaysia (see Appendix 2) reveals consistent trends that align with previous findings. There is considerable variation in the levels of n-3 fatty acids within each fish species, regardless of whether they are farmed or wild, marine or freshwater. For example, the total lipid content of catfish ranges from 4.25 to 20.0 g/100g of edible portion, while the EPA+DHA content of Indian mackerel and yellow striped scad ranges from 76.9 to 872.6 mg/100g and 830.0 to 1798.3 mg/100g of edible portion, respectively (Appendix 2). Furthermore, in general, freshwater fish tend to have lower omega-3 content compared to marine fish. Although it is unfounded for consumers in the current study to claim that wild fish is generally more nutritious than farmed fish in terms of beneficial fats, it is undeniable that commonly consumed wild marine fish, particularly Indian mackerel and scads, serve as significant sources of omega-3 in the diet. In fact, Indian mackerel and yellow-striped scad could be considered suitable local alternatives to imported cold-water fatty fish such as salmon. Additionally, the lower levels of omega-3 and higher saturated fatty acid content observed in farmed freshwater fish in Malaysia do not make them nutritionally superior to other farmed terrestrial livestock. Similarly, a study by Usydus et al. (2011) found that farmed fish imported from China and Vietnam, such as walleye pollock, sole, sutchi catfish, and tilapia, had low levels of EPA and DHA, making them less significant for the prevention of coronary heart disease.

In the Malaysian context, the perception that wild fish is more nutritious is somewhat understandable, although it stems from an unfair comparison between different fish species.

Is the level of contaminants higher in farmed than wild fish? Environmental contaminants, such as dioxins, polychlorinated biphenyls (PCBs), heavy metals, and organochlorine pesticides, pose a global threat to human health. This is because aquatic organisms have the ability to accumulate these contaminants, making the consumption of aquatic food a potential source of chronic exposure (Nøstbakken et al., 2015). Prolonged exposure to these substances can lead to adverse health effects, including an increased risk of cancer, neurotoxicity, and damage to organs and bodily systems in humans (Järup, 2003; Alavanja et al., 2004). Fish accumulate these pollutants in their bodies through two pathways: uptake from water-borne chemicals and ingestion of contaminated food (Streit, 1998). Both wild and farmed fish can be exposed to contaminants released from industrial, agricultural, and municipal waste. However, the concentration of contaminants in fish varies depending on factors such as the origin of the fish, its proximity to pollution sources, the type of tissue sampled, the season of harvest, and, specifically for farmed fish, the composition of their feed (EFSA, 2005; Verbeke et al., 2007).

Studies have shown that the choice of fish culture system and the source of feed play a crucial role in determining the level of contamination in farmed fish. Creti et al. (2010) conducted a study on sea bream, a popular aquaculture species in Italy, to examine the accumulation of cadmium and lead in different fish culture systems. The intensive system, characterized by enclosed environments and the use of contaminated feed, poses a higher risk of metal bioaccumulation compared to the extensive and semi-intensive systems. Similarly, the study by Hites et al. (2004) highlights that farmed salmon tend to contain higher levels of organochlorine contaminants compared to wild salmon.

The available evidence does not provide a conclusive answer regarding whether wild fish consistently have higher dioxin and furan contamination compared to farmed fish. Azlan et al. (2015) conducted a study on marine fish from the Straits of Malacca, finding PCDDs/PCDFs levels ranging from 4.6 to 21.8 pg WHO-TEQ*/g fat, which exceeded the safe limit of 1 pg WHO-TEQ*/g fat set by the Codex Alimentarius Commission. In contrast, Nurul et al.'s 2012 study reported lower PCDDs/PCDFs levels in fish fillet samples of various wild species. Similarly, a 2014 study in Malaysia found lower mean PCDD/PCDF levels in various fish species, including the predominantly farmed ones (Leong et al., 2014). These levels were also lower than those reported by Azlan et al. (2015). Thus, it remains uncertain whether wild fish are consistently more contaminated than farmed fish in terms of dioxins and furans.

Several studies conducted in various countries, including Malaysia, have reported significant variations in the concentrations of heavy metals in both wild and farmed fish species (Fallah et al., 2011; Foran et al., 2004; Padula et al., 2008; Yildiz, 2008; Yipel et al., 2016). Similarly, in Malaysia, studies have indicated that the presence of toxic elements like arsenic, cadmium, lead, and mercury in farmed fish tissues does not consistently show elevated levels compared to wild fish, suggesting no significant threat to human health (Agusa et al., 2007; Alina et al., 2012; Ahmad et al., 2015). The variations in the accumulation of trace elements can be attributed to factors such as feeding habits, habitat, behaviour, ecological needs, and metabolic activity of the fish species (Kalantzi et al., 2013). Additionally, differences in sampling procedures and analytical techniques employed can also impact the results obtained (Alasalvar et al., 2002). The inconsistent adoption of international residue and contaminant nomenclature, along with variations in reporting conventions and sample collection methods, create ambiguity and can lead to different interpretations among consumers (Padula et al., 2008).

While the existing literature does not offer definitive proof, the general perception in the aquaculture industry is that fish farmers hold an advantage in terms of health and safety considerations. Unlike fishermen, fish farmers can manipulate production processes and control the levels of toxic contaminants and pathogens in their fish (Verbeke et al., 2007). Wild fish may accumulate higher levels of trace elements due to uncontrollable factors such as pollution in surface waters or sediments and the concentration of metals in the food chain. Fishermen have limited control over the diet of wild fish, whereas fish farmers can directly regulate tissue contaminant levels through the use of specially formulated diets (EFSA, 2005). Furthermore, fish farmers can minimize risks by conducting proper site evaluations and implementing good aquaculture practices (Jensen and Greenlees, 1997).

However, not all aquaculture operations maintain the same level of adherence to high standards. In Malaysia's aquaculture industry, there is evidence indicating the existence of inconsistent practices. An area of concern is the unregulated usage of prohibited antibiotics in fish feed (Sapkota et al., 2008). While countries like the United States, Canada, and the European Union have banned the use of chloramphenicol in animals intended for food production (Serrano, 2005), sporadic studies in Malaysia have uncovered the frequent occurrence of antibiotic resistance, including resistance to the prohibited chloramphenicol. For instance, multiple shipments of farmed shrimp from Malaysia to the United States were rejected due to the detection of chloramphenicol residue (FDA, 2016). The issuance of an 'import alert' by the US FDA on prawns from Malaysia further underscores the presence of banned antibiotics (FDA, 2016) and underscores the necessity for improved disease management practices in the industry. The extensive media coverage of this news is likely responsible for generating unfavourable perceptions among consumers concerning farmed fish products.

The unregulated use of antimicrobial agents in aquaculture and the presence of their residues in farmed products have significant implications for public health. Ingesting these residues through food consumption can lead to direct health risks, including aplastic anaemia associated with chloramphenicol (WHO, 2006). Prolonged exposure to antibiotics through food can also contribute to the development of antibiotic resistance in harmful bacteria, making it challenging to treat certain microbial diseases in humans (Wegener, 2012). Furthermore, the use of antimicrobials in aquaculture can promote the development of antimicrobial resistance in bacteria, which can be transmitted to humans. Individuals involved in the production chain are at a higher risk of exposure to resistant bacteria, such as methicillin-resistant Staphylococcus aureus (MRSA-398), compared to the general population (Garcia-Alvarez et al., 2012).

While the goal of aquaculture production methods is to ensure fish safety and quality, the current scientific evidence does not provide a conclusive answer regarding the relative safety of farmed fish compared to wild fish. This lack of clarity is reflected in consumer beliefs, as there are equal numbers of respondents who hold neutral views and those who consider farmed fish unsafe. Fish farmers have the potential to benefit from advantages such as enhanced monitoring, traceability, and control over health and safety aspects, but these advantages have not been fully utilized. The presence of unethical farming practices and consumers' limited knowledge about aquaculture systems and fisheries contribute to the understandable perception that wild fish are safer than farmed fish.

CONCLUSIONS

The debate surrounding the consumption of farmed fish versus wild fish is complex and lacks a definitive answer. There is a notable discrepancy between scientific evidence and consumer perceptions, particularly in terms of freshness and sensory characteristics. Although differences in texture may exist due to the fish's life history, proper storage practices can help minimise these disparities. Fish farming provides advantages over capture fisheries, as it allows processors to influence post-mortem biochemistry, freshness, and quality aspects. Aquaculturists have the ability to manipulate various stages of farming and processing to produce fish that meet consumer preferences. Factors influencing fish aroma, such as n-3 PUFA content, diet, and water quality, can be controlled by farmers and fish feed producers, whereas wild fish rely on natural environmental factors beyond human control.

The healthiness and nutritional composition of fish are not clearly defined as they heavily rely on farming conditions. In Europe, studies have been conducted to distinguish the proximate and fatty acid composition between wild and farmed fish for authentication purposes. In Malaysia, it is not possible to directly compare wild and farmed species as commercial fish are exclusively either wild or farmed. Analysis of fatty acid composition in selected Malaysian fish species reveals that popular wild-caught marine fish, like Indian mackerel and scads, contain beneficial omega-3 fatty acids comparable to imported cold-water salmon and have a smaller environmental impact. However, commonly consumed farmed fish in Malaysia, such as tilapia and catfish, have low levels of omega-3 fatty acids and do not offer significant nutritional advantages compared to other farmed terrestrial animal proteins like chicken. Currently, commonly consumed wild-caught marine fish play an irreplaceable role in the Malaysian diet, at least in terms of nutritional value. Simply increasing aquaculture production is not the sole solution to address the decline in wild fish stocks. Aquaculture production systems should focus not only on maximizing yields but also on considering nutritional quality.

The aquaculture industry in Malaysia has been found to have inconsistent practices, resulting in substandard products and damaging the industry's reputation. There is a clear need for improvement in areas such as water quality management, disease control, adherence to good practices, and traceability. Authorities should invest in training and raising awareness among aquaculturists, while also strengthening legislation on fish stocking rate, feed formulation, and antibiotic use. Moreover, consumers have limited knowledge about the potential advantages of aquaculture in terms of controlling and enhancing safety, sensory, and quality aspects of farmed fish when carried out properly. The future success of Malaysian aquaculture depends on enhancing current practices, leveraging its advantages over capture fisheries, and effectively educating consumers about these benefits.

References

Abd Aziz, N., Azlan, A., Ismail, A., Alinafiah, S.M. and Razman, M.R. (2013) Quantitative determination of fatty acids in marine fish and shellfish from warm water of straits of Malacca for nutraceutical purposes. BioMed Research International. Article 284329.

Ackman, R. G., & Hingley, H. J. (1968). The occurrence and retention of dimethyl-β-propiothetin in some filter-feeding organisms. Journal of the Fisheries Board of Canada, 25(2), 267-284.

Ackman, R. G., Dale, J., & Hingley, J. (1966). Deposition of dimethyl-β-propiothetin in Atlantic cod during feeding experiments. Journal of the Fisheries Board of Canada, 23(4), 487-497.

Ackman, R. G., Hingley, J., & MacKay, K. T. (1972). Dimethyl sulfide as an odor component in Nova Scotia fall mackerel. Journal of the Fisheries Board of Canada, 29(7), 1085-1088.

Agusa, T., Kunito, T., Sudaryanto, A., Monirith, I., Kan-Atireklap, S., Iwata, H., Ismail, A., Sanguansin, J., Muchtar, M., Tana, T.S., Tanabe, S. (2007). Exposure assessment for trace elements from consumption of marine fish in Southeast Asia. Environmental Pollution Volume 145, Issue 3, February 2007, Pages 766–777.

Ahmad, N. I., Noh, M. F. M., Mahiyuddin, W. R. W., Jaafar, H., Ishak, I., Azmi, W. N. F. W., ... & Hairi, M. H. (2015). Mercury levels of marine fish commonly consumed in Peninsular Malaysia. Environmental Science and Pollution Research, 22(5), 3672-3686.

Alasalvar, C., Taylor, K. D. A., Zubcov, E., Shahidi, F., & Alexis, M. (2002). Differentiation of cultured and wild sea bass (Dicentrarchus labrax): total lipid content, fatty acid and trace mineral composition. Food chemistry, 79(2), 145-150.

Alavanja, M. C., Hoppin, J. A., & Kamel, F. (2004). Health effects of chronic pesticide exposure: cancer and neurotoxicity. Annu. Rev. Public Health, 25, 155-197.

Alina, M., Azrina, A., Mohd Yunus, A. S., Mohd Zakiuddin, S., Mohd Izuan Effendi, H., & Muhammad Rizal, R. (2012). Heavy metals (mercury, arsenic, cadmium, plumbum) in selected marine fish and shellfish along the Straits of Malacca. International Food Research Journal, 19(1).

Álvarez, V., Trigo, M., Lois, S., Fernández, D., Medina, I., & Aubourg, S. P. (2009). Comparative Lipid Composition Study in Farmed and Wild Blackspot Seabream (Pagellus bogaraveo). CZECH JOURNAL OF FOOD SCIENCES, 27, S274-S276.

Andersen, U. B., Thomassen, M. S., & Rørå, A. M. B. (1997). Texture properties of farmed rainbow trout (Oncorhynchus mykiss): effects of diet, muscle fat content and time of storage on ice. Journal of the Science of Food and Agriculture, 74(3), 347-353.

Andrews, J. (2013, September 11). Formaldehyde Detected in Supermarket Fish Imported from Asia. Food Safety News. Retrieved from: http://www.foodsafetynews.com/2013/09/formaldehyde detected-in-supermarket-fish-imported-from-asia/#.WdhCG_OGPIU

Anon. (2015, October 1) Impose curbs on sale of formalin. Daily Express. Retrieved from: http://www.dailyexpress.com.my/news.cfm?NewsID=103520

Arechavala-Lopez, P., Fernandez-Jover, D., Black, K. D., Ladoukakis, E., Bayle-Sempere, J. T., SanchezJerez, P., & Dempster, T. (2013). Differentiating the wild or farmed origin of Mediterranean fish: a review of tools for sea bream and sea bass. Reviews in Aquaculture, 5(3), 137-157.

Aursand, M. and Axelson, D. (2001) Origin recognition of wild and farmed salmon (Norway and Scotland) using 13C NMR spectroscopy in combination with pattern recognition techniques. In: Magnetic Resonance in Food Science: A View to the Future. Webb, G.A., Belton, P.S., Gil, A.M. and Delgadillo, I. (Eds.). Published by RSC-The Royal Society of Chemistry, pp. 227-231.

Aursand, M., Bleivik, B., Rainuzzo, J.R., Jørgensen, L. and Mohr, V. (1994) Lipid distribution and composition of commercially farmed Atlantic salmon (Salmo salar). J. Sci. Food Agric., 64: 239-248.

Aursand, M., Mabon, F. and Martin, G.J. (2000) Characterization of farmed and wild salmon (Salmo salar) by a combined use of compositional and isotopic analyses. JAOCS., 77: 659-666.

Azlan, A., Nasir, N. N. M., Shamsudin, N., Rahman, H. A., Khoo, H. E., & Razman, M. R. (2015). PCDD and PCDF exposures among fishing community through intake of fish and shellfish from the Straits of Malacca. BMC public health, 15(1), 683.

Bell, J.G., McEvoy, J., Tocher, D.R., McGhee, F., Campbell, P.J. and Sargent, J.R. (2001). Replacement of Fish Oil with Rapeseed Oil in Diets of Atlantic Salmon (Salmo salar) Affects Tissue Lipid Compositions and Hepatocyte Fatty Acid Metabolism. The Journal of Nutrition, 131(5), pp. 1535-1543.

Bhouri, A. M., Bouhlel, I., Chouba, L., Hammami, M., El Cafsi, M., & Chaouch, A. (2010). Total lipid content, fatty acid and mineral compositions of muscles and liver in wild and farmed sea bass (Dicentrarchus labrax). African Journal of Food Science, 4(8), 522-530.

Bjørnevik, M., Karlsen, Ø., Johnston, I. A., & Kiessling, A. (2003). Effect of sustained exercise on white muscle structure and flesh quality in farmed cod (Gadus morhua L.). Aquaculture Research, 34(1), 55- 64.

Borderías, A. J., and Sánchez-Alonso, I. (2011). First Processing Steps and the Quality of Wild and Farmed Fish. Journal of Food Science, 76(1), R1–R5. http://doi.org/10.1111/j.1750- 3841.2010.01900.x

Cahu, C., Salen, P., and de Lorgeril, M. (2004). Farmed and wild fish in the prevention of cardiovascular diseases: Assessing possible differences in lipid nutritional values. Nutrition, Metabolism and Cardiovascular Diseases, 14(1), 34–41. doi:http://dx.doi.org/10.1016/S0939-4753(04)80045-0

Can, M. F., Günlü, A., & Can, H. Y. (2015). Fish consumption preferences and factors influencing it. Food Science and Technology, 35, 339-346.

Carlucci, D., Nocella, G., De Devitiis, B., Viscecchia, R., Bimbo, F., & Nardone, G. (2015). Consumer purchasing behaviour towards fish and seafood products. Patterns and insights from a sample of international studies. Appetite, 84, 212-227.

Chan, N. W. (2012). Managing urban rivers and water quality in Malaysia for sustainable water resources. International Journal of Water Resources Development, 28(2), 343-354.

Chandralekha, A.P.L., Baranage, C. and Samarajeewa, U. (1992) Formaldehyde levels in fish from the Kandy market. Journal of the National Science Foundation of Sri Lanka, 20, 115–121.

Claret, A., Guerrero, L., Ginés, R., Grau, A., Hernández, M. D., Aguirre, E., … Rodríguez-Rodríguez, C. (2014). Consumer beliefs regarding farmed versus wild fish. Appetite, 79, 25–31. doi:http://dx.doi.org/10.1016/j.appet.2014.03.031

Craig, S. R., Helfrich, L. A., Kuhn, D., & Schwarz, M. H. (2017). Understanding fish nutrition, feeds, and feeding. Virginia Cooperative Extension. Publication 420-256

Cretì, P., Trinchella, F., & Scudiero, R. (2010). Heavy metal bioaccumulation and metallothionein content in tissues of the sea bream Sparus aurata from three different fish farming systems. Environmental monitoring and assessment, 165(1-4), 321-329.

Davidson, K., Pan, M., Hu, W., & Poerwanto, D. (2012). CONSUMERS'WILLINGNESS TO PAY FOR AQUACULTURE FISH PRODUCTS VS. WILD-CAUGHT SEAFOOD–A CASE STUDY IN HAWAII. Aquaculture Economics & Management, 16(2), 136-154.

Dionigi, C. P., Johnsen, P. B., & Vinyard, B. T. (2000). The recovery of flavor quality by channel catfish. North American Journal of Aquaculture, 62(3), 189-194.

DoFM (2000 – 2014). National annual fisheries statistics were obtained from official spreadsheets and reports uploaded by the Department of Fisheries, Malaysia on its open data portal:http://www.dof.gov.my/index.php/pages/view/82

Drastini, Y. and Widiasihl, D.A. (2009) Studies on Schiff method for the detection formaldehyde in marine milk fish (Chanos-chanos). Journal of Sains Veterinary, 27, 21–27.

EFSA (2005). Opinion on the scientific panel on contaminants in the food chain on a request from the European Parliament related to the safety assessment of wild and farmed fish. EFSA J, 236, 1-118.

Endinkeau, K. and Tan, K.K. (1993) Profile of Fatty Acid Contents in Malaysian Freshwater Fish, Pertanika J. Trop. Agric. Sci. 16(3): 215-221.

Fallah, A. A., Saei-Dehkordi, S. S., Nematollahi, A., & Jafari, T. (2011). Comparative study of heavy metal and trace element accumulation in edible tissues of farmed and wild rainbow trout (Oncorhynchus mykiss) using ICP-OES technique. Microchemical Journal, 98(2), 275-279.

FAO (2011). Food Supply - Crops Primary Equivalent. Available at http://faostat3.fao.org/download/FB/CC/E

FAO (2016). The State of World Fisheries and Aquaculture 2016. Contributing to food security and nutrition for all. Rome. 200 pp

FAO (2017b). Strengthening capacities, policies and national action plans on prudent and responsible use of antimicrobials in fisheries: Workshop 2 in cooperation with Malaysia Department of Fisheries and INFOFISH (FAO Project FMM/RAS/298). Available at: http://www.fao.org/fi/staticmedia/MeetingDocuments/Workshop2AMR/presentations/26.pdf

FAO and WHO (2012). Code of Practice for fish and fishery products: Second edition. ISBN 978-92-5- 107018-5

Farmer, L. J., McConnell, J. M., & Kilpatrick, D. J. (2000). Sensory characteristics of farmed and wild Atlantic salmon. Aquaculture, 187(1), 105-125.

FDA (2016) Constituent Update: FDA Issues Import Alert on Imported Shrimp and Prawns from Peninsular Malaysia. Available at https://www.fda.gov/Food/NewsEvents/ConstituentUpdates/ucm496475.htm

Flos, R., Reig, L., Oca, J., & Ginovart, M. (2002). Influence of marketing and different land-based systems on gilthead sea bream (Sparus aurata) quality. Aquaculture International, 10(3), 189-206.

Font-i-Furnols, M., & Guerrero, L. (2014). Consumer preference, behavior and perception about meat and meat products: An overview. *Meat science*, *98*(3), 361-371.

Foran, J. A., Hites, R. A., Carpenter, D. O., Hamilton, M. C., Mathews-Amos, A., & Schwager, S. J. (2004). A survey of metals in tissues of farmed Atlantic and wild Pacific salmon. Environmental toxicology and chemistry, 23(9), 2108-2110.

From, J., & Hørlyck, V. (1984). Sites of uptake of geosmin, a cause of earthy-flavor, in rainbow trout (Salmo gairdneri). Canadian Journal of Fisheries and Aquatic Sciences, 41(8), 1224-1226.

Fuentes, A., Fernández-Segovia, I., Serra, J. A., & Barat, J. M. (2010). Comparison of wild and cultured sea bass (Dicentrarchus labrax) quality. Food Chemistry, 119(4), 1514-1518.

Garcia-Alvarez, L., Dawson, S., Cookson, B. and Hawkey, P. (2012). Working across the veterinary and human health sectors. Journal of Antimicrobial Chemotherapy, 67: 37-49.

Goh, E.V., Azam-Ali, S., & McCullough, F. (2023). Fish Purchasing Behavior and Implications for Promoting Sustainable Consumption: A Malaysian Case. The Asian Journal of Business Environment (AJBE), 13(2), 29-37.

Goh, E.V., Azam-Ali, S., Mitra, S. R., & McCullough, F. (2021). Understanding the patterns of fish and seafood consumption and its nutritional roles among a Malaysian population to inform sustainable development. Asia Pacific Journal of Sustainable Agriculture, Food and Energy, 9(1), 1-13.

González, S., Flick, G. J., O'keefe, S. F., Duncan, S. E., McLean, E., & Craig, S. R. (2006). Composition of farmed and wild yellow perch (Perca flavescens). Journal of Food Composition and Analysis, 19(6), 720-726.

Gram, L., & Dalgaard, P. (2002). Fish spoilage bacteria–problems and solutions. Current opinion in biotechnology, 13(3), 262-266.

Grigorakis K., (2007). Compositional and organoleptic quality of farmed and wild gilthead sea bream (Sparus aurata) and sea bass (Dicentrarchus labrax) and factors affecting it: A review. Aquaculture 272, 55-75.

Grigorakis, K. (1999). Quality of cultured and wild gilt-head sea bream (Sparus aurata) and sea bass (Dicentrarchus labrax) (Doctoral dissertation, University of Lincolnshire and Humberside).

Gutierrez, R., Whangchai, N., Sompong, U., Prarom, W., Iwami, N., Itayama, T., ... & Sugiura, N. (2013). Off-flavour in Nile tilapia (Oreochromis niloticus) cultured in an integrated pond-cage culture system. Maejo International Journal of Science and Technology, 7, 1.

Haard, N.F. (1992). Control of chemical composition and food quality attributes of cultured fish. Food Research International, Vol. 25, pp. 289–307.

Hall, T.E. and Amberg, S.M. (2013). Factors influencing consumption of farmed seafood products in the Pacific northwest. Appetite, 2013 Jul; 66:1-9.

Hamilton, M. C., Hites, R. A., Schwager, S. J., Foran, J. A., Knuth, B. A., & Carpenter, D. O. (2005). Lipid composition and contaminants in farmed and wild salmon. Environmental science & technology, 39(22), 8622-8629.

Hardy, R. W. (2003). Farmed fish and omega-3 fatty acids. Aquaculture Magazine, 29(2), 63-65.

Hathurusingha, P. I., & Davey, K. R. (2016). Chemical taste taint accumulation in RAS farmed fish–A Fr 13 risk assessment demonstrated with geosmin (GSM) and 2-methylisoborneol (MIB) in barramundi (Lates calcarifer). Food Control, 60, 309-319.

Henriques, J., Dick, J. R., Tocher, D. R., & Bell, J. G. (2014). Nutritional quality of salmon products available from major retailers in the UK: content and composition of n-3 long-chain PUFA. British Journal of Nutrition, 112(6), 964-975.

Hites, R. A., Foran, J. A., Carpenter, D. O., Hamilton, M. C., Knuth, B. A., & Schwager, S. J. (2004). Global assessment of organic contaminants in farmed salmon. Science, 303(5655), 226-229.

Hoque, M. S., Jacxsens, L., De Meulenaer, B., & Alam, A. N. (2016). Quantitative risk assessment for formalin treatment in fish preservation: food safety concern in local market of Bangladesh. Procedia Food Science, 6, 151-158.

Hossain, M. A. (2011). Fish as source of n-3 polyunsaturated fatty acids (PUFAs), which one is betterfarmed or wild?. Advance Journal of Food Science and Technology, 3(6), 455-466.

Hossain, M. A., and Wahab, M. A. (2011). The Diversity of Cypriniforms Throughout Bangladesh. Nova Science Publishers, Incorporated.

Hunter, B. J., Allan, G. L., & Roberts, D. C. (2001). Lipid composition of farmed versus wild silver perch Bidyanus bidyanus: theoretical impact on a human diet. Australian Journal of Nutrition and Dietetics, 58(1), 45-51.

Hurlburt, B.K., Brashear, S.S., Lloyd, S.W., Grimm, C.C., Thomson, J.L. and Zimba, P.V. 2009. Impact of weather on off-flavour episodes at a Louisiana commercial catfish farm. Aquaculture Research, 40(5): 566-574.

Igarashi, T., Aursand, M., Sacchi, R., Paolillo, L., Nonaka, M. and Wada, S. (2002) Determination of docosahexaenoic acid and n-3 fatty acids in refined fish oils by 1 H-NMR spectroscopy: IUPAC interlaboratory study. J. AOAC Int., 85: 1341-1354.

Izquierdo, M. S., Montero, D., Robaina, L., Caballero, M. J., Rosenlund, G., & Ginés, R. (2005). Alterations in fillet fatty acid profile and flesh quality in gilthead seabream (Sparus aurata) fed vegetable oils for a long term period. Recovery of fatty acid profiles by fish oil feeding. Aquaculture, 250(1), 431-444.

Jamilah, B., A. Nurul, S. Yusoff and B.H.A. Faujan. 2001. Identification of aroma, earthy flavor and after taste in Tilapia using sensory evaluation technique. Pertanika Journal of Tropical Agricultural Science 24(2): 95-100.

Järup, L. (2003). Hazards of heavy metal contamination. British medical bulletin, 68(1), 167-182.

Jensen, G. L., & Greenlees, K. J. (1997). Public health issues in aquaculture. Revue scientifique et technique (International Office of Epizootics), 16(2), 641-651.

Johnsen, P. B., Civille, G. V., & Vercelloti, J. R. (1987). A lexicon of pond-raised catfish flavor descriptors. Journal of Sensory Studies, 2(2), 85-91. Johnston, R. J., Wessells, C. R., Donath, H., and Asche, F. (

Jones, B., Fuller, S., & Carton, A. G. (2013). Earthy-muddy tainting of cultured barramundi linked to geosmin in tropical northern Australia. Aquaculture Environment Interactions, 3(2), 117-124.

Josephson, D. B., & Lindsay, R. C. (1986). Enzymic generation of volatile aroma compounds from fresh fish.

Kalantzi, I., Black, K. D., Pergantis, S. A., Shimmield, T. M., Papageorgiou, N., Sevastou, K., & Karakassis, I. (2013). Metals and other elements in tissues of wild fish from fish farms and comparison with farmed species in sites with oxic and anoxic sediments. Food chemistry, 141(2), 680- 694.

Kalidoss Manikandan, N. F., & Prabu, E. (2020). A review on the application and effect of carotenoids with respect to canthaxanthin in the culture of fishes and crustaceans. *International Journal of Fisheries and Aquatic Studies*, *8*(5), 128-133.

Karapanagiotidis, I. T., Bell, M. V., Little, D. C., Yakupitiyage, A., & Rakshit, S. K. (2006). Polyunsaturated fatty acid content of wild and farmed tilapias in Thailand: effect of aquaculture practices and implications for human nutrition. Journal of Agricultural and Food Chemistry, 54(12), 4304-4310.

Katrin Schlag, A., & Ystgaard, K. (2013). Europeans and aquaculture: perceived differences between wild and farmed fish. British Food Journal, 115(2), 209-222.

Leong, Y.H., Chiang, P.N., Jaafar, H.J., Gan, C.Y., and Majid, M.I.A. (2014). Contamination of food samples from Malaysia with polychlorinated dibenzo-p-dioxins and dibenzofurans and estimation of human intake. Food Addit Contam. 2014;31:711–718. doi: 10.1080/19440049.2014.880519.

Lövkvist, S. (2014). An investigation of the lipid content and lipid composition in Atlantic salmon, pink salmon and striped catfish, obtained at the local retailers in Uppsala, Sweden.

Martinsen, C., Lauby, B. B., Nevissi, A., & Brannon, E. (1992). The influence of crude oil and dispersant on the sensory characteristics of steelhead (Oncorhynchus mykiss) in marine waters. Journal of Aquatic Food Product Technology, 1(1), 37-52.

Ministry of Health Singapore (2011). Singapore Food Composition Database: Energy and Nutrient Composition of Food. Available from: focos.hpb.gov.sg/eservices/ENCF/

Montero, D., Robaina, L., Caballero, M. J., Ginés, R., & Izquierdo, M. S. (2005). Growth, feed utilization and flesh quality of European sea bass (Dicentrarchus labrax) fed diets containing vegetable oils: a time-course study on the effect of a re-feeding period with a 100% fish oil diet. Aquaculture, 248(1), 121-134.

Muhamad, N.A. and Mohamad, J. (2012) Fatty Acids Composition of Selected Malaysian Fishes (Komposisi Asid Lemak Ikan Terpilih Malaysia). Sains Malaysiana 41(1)(2012): 81–94

Murray, J. and Burt, J.R. (2001). The Composition of Fish. Torry Advisory Note No. 38, Ministry of Technology. Torry Research Station, U.K., 14 pp.

NCFFN (2005). National Coordinating Committee on Food and Nutrition: Recommended Nutrient Intakes for Malaysia. Ministry of Health Malaysia, Kuala Lumpur.

Nettleton, J. A., & Exler, J. (1992). Nutrients in wild and farmed fish and shellfish. Journal of Food Science, 57(2), 257-260.

Noordiana, N., Fatimah, A. B. and Farhana, Y. C. B. (2011). Formaldehyde content and quality characteristics of selected fish and seafood from wet markets. International Food Research Journal 18(1): 125-136.

Nøstbakken, O. J., Hove, H. T., Duinker, A., Lundebye, A. K., Berntssen, M. H., Hannisdal, R., ... & Julshamn, K. (2015). Contaminant levels in Norwegian farmed Atlantic salmon (Salmo salar) in the 13- year period from 1999 to 2011. Environment international, 74, 274-280.

Nurul Izzah, A., F.B.H. Ahmad, B. Jamilah and Y. Salmah. 2004. Geosmin and isoborneol in black tilapia (Oreochromis mossambica). Ultra Science 16(2): 151-154.

Nurul Izzah, A., F.B.H. Ahmad, B. Jamilah and Y. Salmah. 2000. Volatile flavor and off-flavour components in black tilapia (O-mossambica) cultured in ex-tin mines. Research Journal of Chemistry and Environment 4(3): 67-72.

Nurul, N., Azrina, A., Muhammad, R. R., Nor, A. R., & Latiff, A. A. (2012). PCDDs and PCDFs in pelagic fish along the Straits of Malacca. Pertanika Journal of Tropical Agricultural Science, 35(4), 779-794.

Olsson, G. B., Olsen, R. L., Carlehög, M., & Ofstad, R. (2003). Seasonal variations in chemical and sensory characteristics of farmed and wild Atlantic halibut (Hippoglossus hippoglossus). Aquaculture, 217(1), 191-205.

Orban, E., Sinesio, F., & Paoletti, F. (1997). The functional properties of the proteins, texture and the sensory characteristics of frozen sea bream fillets (Sparus aurata) from different farming systems. LWT-Food Science and Technology, 30(2), 214-217.

Osman, H., Suriah, A.R. and Law, E.C. (2001). Fatty acid composition and cholesterol content of selected marine fish in Malaysian waters. Food Chemistry 73: 55-60.

Padula, D. J., Daughtry, B. J., & Nowak, B. F. (2008). Dioxins, PCBs, metals, metalloids, pesticides and antimicrobial residues in wild and farmed Australian southern bluefin tuna (Thunnus maccoyii). Chemosphere, 72(1), 34-44.

Percival, S., Drabsch, P., & Glencross, B. (2008). Determining factors affecting muddy-flavour taint in farmed barramundi, Lates calcarifer. Aquaculture, 284(1), 136-143.

Pimolrat, P., Whangchai, N., Chitmanat, C., Itayama, T., & Lebel, L. (2015). Off-flavor Characterization in high nutrient load Tilapia ponds in northern Thailand.

Rasmussen, R. S. (2001). Quality of farmed salmonids with emphasis on proximate composition, yield and sensory characteristics. Aquaculture Research, 32(10), 767-786.

Robertson, R. F., Hammond, A., Jauncey, K., Beveridge, M. C. M., & Lawton, L. A. (2006). An investigation into the occurrence of geosmin responsible for earthy–musty taints in UK farmed rainbow trout, Onchorhynchus mykiss. Aquaculture, 259(1), 153-163.

Robin, J., Cravedi, J. P., Hillenweck, A., Deshayes, C., & Vallod, D. (2006). Off flavor characterization and origin in French trout farming. Aquaculture, 260(1), 128-138.

Ruiz-Lopez, N., Sayanova, O., Napier, J.A., and Haslam, R.P. (2012). Metabolic engineering of the omega-3 long chain polyunsaturated fatty acid biosynthetic pathway into transgenic plants. J Exp Bot. 2012;63:2397–2410. doi: 10.1093/jxb/err454.

Rusli, M. H. B. M. (2012). Protecting vital sea lines of communication: A study of the proposed designation of the Straits of Malacca and Singapore as a particularly sensitive sea area. Ocean & Coastal Management, 57, 79-94.

Sapkota, A., Sapkota, A. R., Kucharski, M., Burke, J., McKenzie, S., Walker, P., & Lawrence, R. (2008). Aquaculture practices and potential human health risks: current knowledge and future priorities. Environment international, 34(8), 1215-1226.

Schlag, A.K. and Ystgaard, K. (2013). Europeans and aquaculture: perceived differences between wild and farmed fish. British Food Journal, Vol. 115 Iss: 2, pp.209 – 222.

Sérot, T., Gandemer, G., & Demaimay, M. (1998). Lipid and fatty acid compositions of muscle from farmed and wild adult turbot. Aquaculture International, 6(5), 331-343.

Serrano, P. H. (2005). Responsible use of antibiotics in aquaculture (No. 469). Food & Agriculture Org.

Siti Aminah, A., Zailina. H., Fatimah, A.B. (2013). Health risk Assessment of adults consuming commercial fish contaminated with formaldehyde. Food and Public Health, 3(1), 52-58.

Smith, J. L., Boyer, G. L., & Zimba, P. V. (2008). A review of cyanobacterial odorous and bioactive metabolites:

impacts and management alternatives in aquaculture. Aquaculture, 280(1), 5-20.

Sprague, M., Dick, J. R., & Tocher, D. R. (2016). Impact of sustainable feeds on omega-3 long-chain fatty acid levels in farmed Atlantic salmon, 2006–2015. Scientific reports, 6, 21892.

Streit, B. (1998). Bioaccumulation of contaminants in fish. In Fish Ecotoxicology (pp. 353-387). Birkhäuser Basel.

Strobel, C., Jahreis, G., & Kuhnt, K. (2012). Survey of n-3 and n-6 polyunsaturated fatty acids in fish and fish products. Lipids in health and disease, 11(1), 144.

Suyama, M., Hirano, T., Yamazake S. (1985). Quality of wild and cultured ayu. VI. Odor of ayu and its volatile components. Bulletin of the Japanese Society of Scientific Fisheries, 51(2), 287-294.

Tan, S.C., Ong, K.J., and Raman, A. (2012, March 24). CAP: Formalin may have been used to preserve fish. The Star Newspaper. Retrieved from: http://www.thestar.com.my/news/nation/2012/03/24/cap-formalin-may-have-been-used-topreserve-fish/#AdWBdLIKoiIq73gj.99

Tang, X., Bai, Y., Duong, A., Smith, M.T., Li, L. and Zhang, L. (2009) Formaldehyde in China: production, consumption, exposure levels, and health effects. Environment international, 35, 1210−124.

Tocher, D. R. (2010). Fatty acid requirements in ontogeny of marine and freshwater fish. Aquaculture Research, 41(5), 717-732.

Tunhun, D., Kanont, S., Chaiyawat, M., and Raksakulthai, N. (1996). Detection of illegal addition of formaldehyde to fresh fish. ASEAN Food J. 11 : 74-77.

USDA (2015). United States Department of Agriculture and Department of Health and Human Services: Scientific Report of the 2015 Dietary Guidelines Advisory Committee. Available at: http://health.gov/dietaryguidelines/2015-scientific-report/pdfs/scientific-report-of-the-2015- dietary-guidelines-advisory-committee.pdf

Usydus, Z., Szlinder-Richert, J., Adamczyk, M., & Szatkowska, U. (2011). Marine and farmed fish in the Polish market: Comparison of the nutritional value. Food Chemistry, 126(1), 78-84.

Vanhonacker, F., Altintzoglou, T., Luten, J., and Verbeke, W. (2011). Does fish origin matter to European consumers?: Insights from a consumer survey in Belgium, Norway and Spain. British Food Journal, Vol. 113 Iss: 4, pp.535 – 549.

Vanhonacker, F., Van Loo, E. J., Gellynck, X., and Verbeke, W. (2013). Flemish consumer attitudes towards more sustainable food choices. Appetite, 62, 7–16. doi:http://dx.doi.org/10.1016/j.appet.2012.11.003

Venugopal, V. (Ed.). (2005). Seafood processing: adding value through quick freezing, retortable packaging and cook-chilling. CRC press.

Verbeke, W. and Vackier, I. (2005). Individual determinants of fish consumption: application of the theory of planned behaviour, Appetite, Vol. 44, pp. 67–82.

Verbeke, W., Sioen, I., Pieniak, Z., Van Camp, J., and De Henauw, S. (2005). Consumer perception versus scientific evidence about health benefits and safety risks from fish consumption. Public Health Nutr. 2005;8:422-429

Verbeke, W., Vanhonacker, F., Sioen, I., Camp, J.V. and De Henauw, S. (2007). Perceived importance of sustainability and ethics related to fish: a consumer behavior perspective. Ambio, Vol. 36(7) , 580– 585.

Wegener, H. C. (2012). Antibiotic resistance—linking human and animal health. In Improving food safety through a one health approach: workshop summary (p. 331). National Academies Press.

WHO (2006). Toxicological evaluation of certain veterinary drug residues in food (Vol. 57). World Health Organization.

WHO (2008) Interim Summary of Conclusions and Dietary Recommendations on Total Fat and Fatty Acids From the Joint FAO/WHO Expert Consultation on Fats and Fatty Acids in Human Nutrition. Geneva: 2008 Nov 10-14

Wooster, G. A., Martinez, C. M., Bowser, P. R., & O'Hara, D. S. (2005). Human health risks associated with formalin treatments used in aquaculture: initial study. North American Journal of Aquaculture, 67(2), 111-113.

Yildiz, M. (2008). Mineral composition in fillets of sea bass (Dicentrarchus labrax) and sea bream (Sparus aurata): a comparison of cultured and wild fish. Journal of Applied Ichthyology, 24(5), 589- 594.

Yipel, M., Erdinç, T. Ü. R. K., Tekeli, I. O., & Halis, O. Ğ. U. Z. (2016). Heavy Metal Levels in Farmed and Wild Fishes of Aegean Sea and Assessment of Potential Risks to Human Health. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 22(6), 889-894.

Zimba, P.V. and Grimm, C.C. 2003. A synoptic survey of musty/muddy odor metabolites and microcystin toxin occurrence and concentration in southeastern USA channel catfish (Ictalurus punctatus Ralfinesque) production ponds. Aquaculture, 218(1-4): 81-87.

APPENDIX

Appendix 1: List of Farmed Fish Species Commonly Available in Klang Valley, Malaysia

Local Name	**English Name**	**Latin name**
Siakap	Seabass/ Barramundi	*Lates calcarifer*
Tilapia	Tilapia	*Oreochromis spp.*
Patin	Silver Catfish	*Barbonymus gonionotus*
Keli	Catfish	*Clarias batrachus*
Salmon	Salmon	*Salmo salar*
Dory	Dory	*Pangasius sutchi*
Bawal Emas	Golden Pomfret	*Trachinotus Ovatus*
Kerapu	Grouper	*Epinephelinae spp.*
Jelawat	Hoven's Carp	*Leptobarbus hoevenii*
Kap/Tongsan/ Rohu	Common Carps	*Cyprinus carpio*
Jenahak	Snapper	*Lutjanidae spp.*
Udang Putih	Whiteleg Prawn	*Penaeus vannamei*
Udang Harimau	Tiger Prawn	*Penaeus monodon*
Udang Galah	Freshwater Scampi	*Macrobrachium rosenbergii*
Siput/ Kupang	Mussels	*Perna canaliculus*
Kerang	Blood Cockles	*Anadara granosa*
Toman	Snakehead	*Channidae spp.*
Lampan	Java Barb	*Barbonymus gonionotus*

Appendix 2: Content of total fat, Omega 3 fatty acid and EPA+DPA in popularly consumed fishes in Malaysia. (References listed in the table below.)

Common Wild Captured Marine Fish	Total Fat (g/100g Edible Portion)[a]	PUFA ω-3 (mg/100g Edible Portion)[a]	EPA + DHA (mg/100g Edible Portion)[a]
Spanish Mackerel *(Scomberomorus commerson)*	**x̄=1.47**	**x̄=470.2**	**x̄=341.0**
Abd Aziz et al. (2013)	1.05	314.2	97.5
Osman et al. (2001)	1.46	626.2	425.6
Ministry of Health Singapore (2011)	1.90	-	500.0
Stingray *(Dasyatidae spp.)*	**x̄=1.03**	**x̄=567.3**	**x̄=161.1**
Abd Aziz et al. (2013)	0.93	375.5	11.7
Osman et al. (2001)	1.95	759.1	441.7
Ministry of Health Singapore (2011)	0.22	-	30.0
Fourfinger Threadfin *(Eleutheronema tetradactylum)*	**x̄=1.78**	**x̄=562.6**	**x̄=251.8**
Abd Aziz et al. (2013)	2.10	460.6	149.3
Osman et al. (2001)	2.24	664.6	354.3
Ministry of Health Singapore (2011)	1.00	-	-
Silver Pomfret *(Pampus argenteus)*	**x̄=3.20**	**x̄=747.5**	**x̄=414.7**
Abd Aziz et al. (2013)	2.09	571.6	264.3
Osman et al. (2001)	2.91	923.3	573.9
Ministry of Health Singapore (2011)	4.60	-	406.0
Black Pomfret *(Parastromateus niger)*	**x̄=3.24**	**x̄=782.4**	**x̄=509.4**
Abd Aziz et al. (2013)	2.33	714.3	350.6
Osman et al. (2001)	2.79	850.4	405.6
Ministry of Health Singapore (2011)	4.60	-	772.0
Hardtail Scad *(Megalaspis cordyla)*	**x̄=2.72**	**x̄=931.0**	**x̄=761.1**
Abd Aziz et al. (2013)	1.53	387.0	214.9
Osman et al. (2001)	3.08	1475.0	1058.3
Ministry of Health Singapore (2011)	3.55	-	1010.0
Indian Mackerel *(Rastrelliger kanagurta)*	**x̄=3.2**	**x̄=1048.1**	**x̄=505.5**
Muhamad et al. (2012)	4.54	1438.3	702.4
Abd Aziz et al. (2013)	1.80	190.5	76.9
Osman et al. (2001)	4.54	1515.5	872.6
Ministry of Health Singapore (2011)	1.73	-	370.0
Yellow Striped Scad *(Selaroides leptolepis)*	**x̄=3.26**	**x̄=1898.6**	**x̄=1169.2**
Abd Aziz et al. (2013)	2.12	1417.0	879.15
Osman et al. (2001)	5.77	2380.1	1798.3
Ministry of Health Singapore (2011)	1.90	-	830.0
Threadfin Bream (*Nemipterus bathybius)*	**x̄=3.07**	**x̄=796.5**	**x̄=551.7**
Abd Aziz et al. (2013)	2.70	796.5	551.7
Ministry of Health Singapore (2011)	3.43	-	-

Sardine *(Sardinella spp)*	**x̄=3.79**	**x̄=839.5**	**x̄=549.7**
Abd Aziz et al. (2013)	3.00	734.6	436.9
Osman et al. (2001)	3.06	944.3	662.5
Ministry of Health Singapore (2011)	5.30	-	-
Anchovies *(Stolephorus spp.)*	**x̄=2.80**	**x̄=727.0**	**x̄=129.5**
Muhamad et al. (2012)	2.50	727.0	129.5
Ministry of Health Singapore (2011)	3.10	-	-
Common Farmed Fish	**Total Fat (g/100g Edible Portion)**	**PUFA ω-3 (mg/100g Edible Portion)**	**EPA + DHA (mg/100g Edible Portion)**
Catfish *(Clarias batrachus)*	**x̄=12.01**	**x̄=195.4**	**x̄=36.7**
Muhamad et al. (2012)	4.25	236.7	31.5
Endinkeau and Tan (1993)	12.96	111.5	71.3
Abd Rahnan et al. (1995)	20.0	238.0	44.0
Ministry of Health Singapore (2011)	10.83	-	-
Barramundi *(Lates calcarifer)*	**x̄=2.81**	**x̄=509.4**	**x̄=220.0**
Abd Aziz et al. (2013)	2.68	933.0	234.9
Endinkeau and Tan (1993)	1.97	153.1	151.5
Abd Rahnan et al. (1995)	6.50	442.0	273.7
Ministry of Health Singapore (2011)	0.10	-	-
Tilapia *(Oreochromis spp.)*	**x̄=5.19**	**x̄=202.7**	**x̄=60.0**
Endinkeau and Tan (1993)	11.01	210.3	96.9
Abd Rahnan et al. (1995)	2.75	195.0	23.1
Ministry of Health Singapore (2011)	1.80	-	-
Golden Snapper *(Lutjanus inermis)*	**x̄=1.60**	**x̄=506.3**	**x̄=146.0**
Abd Aziz et al. (2013)	1.29	506.3	25.9
Ministry of Health Singapore (2011)	1.90	-	266.0
Red Snapper *(Lutjanus campechanus)*	**x̄=1.64**	**x̄=724.7**	**x̄=282.0**
Abd Aziz et al. (2013)	1.37	724.7	234.0
Ministry of Health Singapore (2011)	1.90	-	330.0

Common Terrestrial Animals	Total Fat (g/100g Edible Portion)	PUFA ω-3 (mg/100g Edible Portion)	EPA + DHA (mg/100g Edible Portion)
Chicken (Ground)			
Ministry of Health Singapore (2011)	**8.1**	-	**31.0**
Beef (Lean)			
Ministry of Health Singapore (2011)	**3.7**	-	**25.0**
Pork (Lean)			
Ministry of Health Singapore (2011)	**1.6**	-	**6.0**

[a] To assess the omega-3 contents of commonly consumed and commercially important fish in Malaysia, a review was conducted to gather data from Malaysian papers. A total of 8 studies were identified through searches on platforms like ScienceDirect and Google Scholar, using keywords such as "fatty acid composition," "fish," and "Malaysia." Out of these, 6 studies were selected, while 2 were excluded due to insufficient data. The relevant data from the selected papers were extracted, converted, and expressed as milligrams per 100 grams of edible portion, and then averaged accordingly. To facilitate comparison, data from the Singapore Food Composition Database (Ministry of Health Singapore, 2011) were also included where available. Additionally, some other protein sources, such as salmon (which is more popular among urbanites), and popular terrestrial animals, were included for comparison purposes. The Malaysian Food Composition Database was not consulted as it did not provide measurements for fatty acid composition.

[*] Farmed Atlantic