

SENSORY EVALUATION OF FILLETS FROM TILAPIA (*Oreochromis niloticus*) FED DIETS CONTAINING OIL PALM LIPIDS

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ABSTRACT

This study aimed to investigate the effects of feeding tilapia (*Oreochromis niloticus*) with a diet containing oil palm lipids on the sensory evaluation of tilapia fillet in relation to commercial and control feeds. Six tilapia fish grower diets were formulated with the inclusion of emulsified palm fatty acid distillate (Malaysian Palm Oil Board-High Energy, MPOB-HIE) and crude palm oil (CPO) at 5%, 8% and 10%. The negative control diet was made using similar raw materials, but without the inclusion of any lipid, while the commercial diet was used as a positive control. Thirty panellists were recruited from the staff of the Malaysian Palm Oil Board and students, without any specific priority in selection. Each panellist was required to evaluate steamed fish fillet samples on six attributes, namely colour, texture (firmness and sliminess), aroma, taste and overall quality using a nine-point hedonic scale of a quantitative descriptive analysis method. There were no significant differences ($P > 0.05$) in all sensory attributes among fillets of tilapia fed with different dietary treatments. The results of this study suggest that the incorporation of CPO and MPOB-HIE in tilapia feed formulation did not impart any negative effects on the sensory properties of the tilapia fillets.

Keywords: sensory evaluation, tilapia fillet, crude palm oil.

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INTRODUCTION

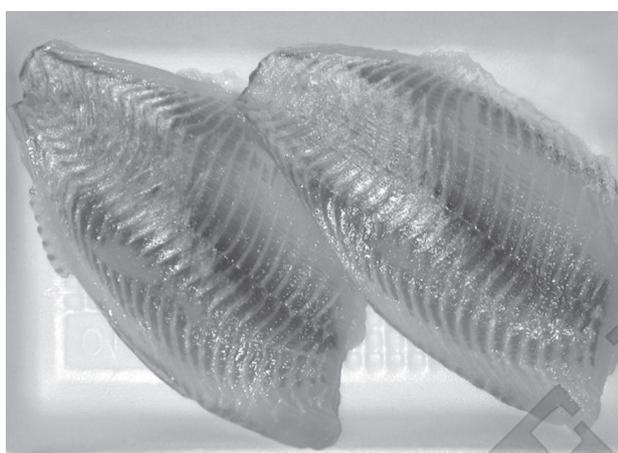
Aquaculture is one of the major sectors in Malaysia that contributes to the economy of the nation and to the income of local fishers. In 2017, the total fishery production of the country amounted to 1.7 million tonnes, with 1.5 and 0.2 million tonnes of both fisheries and aquaculture productions, respectively (FAO, 2019). The overall demand for fish in Malaysia is projected to increase to around 1.93 million tonnes by 2020 (Yusoff, 2015). The rise in demand for fish is attributed to the increasing population and preferences for fish consumption. Fish is one of the nutritious foods that contain high-quality proteins, vitamins and minerals. The availability of local

fish, derived from 65% of coastal fisheries and the remaining from deep-sea fishing, has contributed to positive food security and will increase foreign exchange earnings through the production of value-added fish and fishery products for international trade (Yusoff, 2015).

Tilapia (*Oreochromis niloticus*), also known as Nile tilapia, is a lean fish species found in warm waters with good commercial potential (Bolivar *et al.*, 2004). Tilapia is the second most farmed fish in the world and its production has quadrupled over the last decade due to the ease of aquaculture, marketability and stable market prices (Wang and Lu, 2016). Tilapia and value-added tilapia products are also classified as food fish and cash crops in developing countries, particularly in Asia (Abdel-Fattah, 2019). Tilapia has been a popular freshwater species reared by farmers in Malaysia due to its high demand and affordability. The production of tilapia culture began with a land-

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based system followed by floating net cages and, recently, by polar-circle high-density polyethylene cages to increase productivity. Tilapia aquaculture must follow sustainable practices for continued production and improved sustainability (Wang and Lu, 2016). Local tilapia production reached 35 400 t in 2015, priced at RM 248 million (Metro News, 2016). The Malaysian Department of Fisheries has set a tilapia development target of 130 000 t by 2020 to meet the national demand. Traditionally, tilapia has been exported to other countries in a variety of product forms, such as frozen fillets (Figure 1) and whole fish (Conte *et al.*, 2014), but lately frozen fillets, which have been offered in various sizes and packaging styles, have become more common and convenient and more favoured by consumers.



Source: Ng and Bahurmiz (2010).

Figure 1. Frozen tilapia fish fillets offered in the market.

Feed plays an important role in influencing the performance of cultivated fish (*e.g.* tilapia, carp, catfish and trout) and is influenced by factors such as behaviour of fish, stocking density, feed quality, daily ration size, feeding frequency and water temperature (Firew *et al.*, 2019). About 70% of the total cost of fish production is from fish feeds, which is the highest cost in fish farming operations (Paul *et al.*, 2018). Fish oil is commonly used in the processing of fish feed as a source of energy, but supplies are very limited. Since the price of fish oil is too expensive, replacing the energy source with vegetable oils can be an alternative to the conventional fish oil as well as reducing the dependency on imported corn grain in the fish feed industry due to stable prices and abundant supply (Babalola and Apata, 2012).

Being the world's most-produced vegetable oil, crude palm oil (CPO) could potentially be an alternative to fish oil in aquafeeds (Ng, 2006). CPO is rich in carotenes (provitamin A) and vitamin E consisting of tocopherols and tocotrienol

homologues (Nesaretnam and Muhammad 1993). Carotenes and vitamin E have strong antioxidant properties (Loganathan *et al.*, 2009). CPO also contains a high proportion of essential fatty acid (EFA), *i.e.* linoleic acid. Palm fatty acid distillates (PFAD), which have a substantial quantity of nutritious micronutrients, such as vitamin E, is a by-product obtained during CPO refining (Bonnie and Yusof, 2009). The Malaysian Palm Oil Board-High Energy (MPOB-HIE) is a specialty feed ingredient formulated using PFAD and a food grade emulsifier (Wan Nooraida and Abidah, 2020). The role of the emulsifier is to improve the digestion of lipids by the animals (Osman *et al.*, 2009).

Oil palm lipids, especially CPO and PFAD, have an enormous potential to be used in fish diets and a bright future in the aquaculture sector based on their nutritional values and economic price. Both CPO and PFAD also have a positive impact on improving the quality of fish flesh (Ng, 2004). A study conducted by Ng and Bahurmiz (2010) found that tilapia fillets fed with oil-based palm diets exhibit higher oxidative stability during frozen storage than tilapia fillets fed with fish oil-based diets. Improving oxidative stability, in turn, can help to extend the shelf-life of tilapia fillets.

Supplementation of natural antioxidants (carotenoids and vitamin E) rich in oil palm lipids in the fish feed formulation can add value to the final products as these antioxidants could be deposited in fish fillets. The antioxidants could improve the oxidative stability of tilapia fillets. Tilapia fillets fed diet supplemented with other vegetable oils containing a significant amount of omega-6 polyunsaturated fatty acids (PUFA) that are easily oxidised, making the final products easily rancid. Ng *et al.* (2004) observed an accumulation of the natural palm vitamin E in the tilapia fillets by feeding tilapia fish with diets supplemented with a palm-based tocotrienol-rich fraction (TRF). The presence of the palm TRF in the tilapia fillet provides strong oxidative stability to the tilapia fillets (Ng *et al.*, 2006). Moreover, the low concentration of PUFA in oil palm lipids also helps to reduce the effects of oxidation (Ng *et al.*, 2013). Thus, the combination of these two factors decreased the incidence of rancidity in fish fillets. In addition, freshness, taste and long-term storage properties of the fish fillet are relatively increased when fed the oil palm lipid sources.

Freshness is an important quality parameter in fish and fish products and is of great concern in the fish sector and fish inspection service (Martinsdottir, 2002; Martinsdottir *et al.*, 2000). Sensory is the most relevant tool for evaluating freshness in fisheries. Sensory assessment is characterised as a scientific approach to stimulating, quantifying, assessing and interpreting food and material-related reactions of people through vision, smell, taste, touch and hearing (Huss, 1995). Sensory evaluation needs

to be carried out to determine the acceptability of food products by the customer, leading to effective product adjustment and efficient market launch. The goal of this study was therefore to investigate the effect of feeding tilapia fish with diet containing oil palm lipids (MPOB-HIE and CPO) on the sensory evaluation of tilapia fish fillets in comparison to commercial and control feeds.

MATERIALS AND METHODS

Materials

Mixed-sex tilapia fingerlings (*Oreochromis niloticus*) were purchased from Aqasia Aquatic, Seremban, Negeri Sembilan, Malaysia and transported alive to the Feed Research Group, MPOB Keratong Research Station, Pahang, Malaysia. Raw materials for floating tilapia fish feed production (fishmeal, soyabean meal, corn, broken rice, wheat pollard and feed additives) were purchased from local suppliers. PFAD and CPO were obtained from Felda Vegetable Oil Product (FVOP), Gebeng, Pahang. Starter and grower floating tilapia fish feeds were produced using an extruder machine at Shuzam Feedmill, Seremban 2, Negeri Sembilan.

The commercial feed, Cargill® was purchased from a local supplier in Segamat, Johor, Malaysia.

Feeding Trial

Feed formulations of tilapia starter and grower diets are shown in *Tables 1* and *2*, respectively. Control feed (CNT) was made using similar raw materials with treatment feeds, but without any oil palm lipids inclusion as negative control while commercial feed (COM) was used as positive control. The proximate composition of starter and grower feeds are presented in *Tables 3* and *4*, respectively. All treatments, CNT and COM feeds met the recommended starter and grower feed requirements for tilapia fish (Malaysia Standard, 2013). A total of 600 tilapia fingerlings with an initial mean weight of about 23.0 g were randomly allocated to the eight treatments with three replications per treatment (n=25). All tilapia fish were fed with the commercial feed diet for the first two weeks during the adaptation period and continued with the experimental feed diets for the subsequent 22 weeks. Starter feeds were fed to the tilapia fish from Week 2 to Week 12 followed by grower feeds from Week 13 to Week 24. Six fish per replication were randomly selected for sensory evaluation at Week 24.

TABLE 1. TILAPIA STARTER FEED FORMULATION

Ingredients (%)	MPOB-HIE			CPO			CNT
	5%	8%	10%	5%	8%	10%	
Fishmeal	10.00	7.00	5.00	10.00	7.00	5.00	7.00
Soyabean meal	46.50	51.00	54.00	46.50	51.00	54.00	46.00
Corn	18.80	14.30	11.30	18.00	13.50	10.50	20.00
Broken rice	15.00	15.00	15.00	15.80	15.80	15.80	22.30
Wheat pollard	0.50	0.50	0.50	0.50	0.50	0.50	0.50
MPOB-HIE	5.00	8.00	10.00	0.00	0.00	0.00	0.00
CPO	0.00	0.00	0.00	5.00	8.00	10.00	0.00
Feed additives*	4.20	4.20	4.20	4.20	4.20	4.20	4.20

Note: CNT - control diet; CPO - diet containing crude palm oil; MPOB-HIE - diet containing emulsified palm fatty acid distillates. *Feed additives consist of dicalcium phosphate, calcium propionate, fish hydrolysate, vitamin and mineral premixes.

TABLE 2. TILAPIA GROWER FEED FORMULATION

Ingredients (%)	MPOB-HIE			CPO			CNT
	5%	8%	10%	5%	8%	10%	
Fishmeal	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Soyabean meal	48.00	48.60	49.00	48.00	48.60	49.00	42.90
Corn	17.30	13.70	11.30	17.30	13.70	11.30	20.00
Broken rice	20.00	20.00	20.00	20.00	20.00	20.00	27.40
Wheat pollard	0.50	0.50	0.50	0.50	0.50	0.50	0.50
MPOB-HIE	5.00	8.00	10.00	0.00	0.00	0.00	0.00
CPO	0.00	0.00	0.00	5.00	8.00	10.00	0.00
Feed additives*	4.20	4.20	4.20	4.20	4.20	4.20	4.20

Note: CNT - control diet; CPO - diet containing crude palm oil; MPOB-HIE - diet containing emulsified palm fatty acid distillates. *Feed additives consist of dicalcium phosphate, calcium propionate, fish hydrolysate, vitamin and mineral premixes.

TABLE 3. PROXIMATE COMPOSITION OF TILAPIA STARTER FISH FEED

Proximate analysis (%)	MPOB-HIE			CPO			CNT	COM	Standard specification*
	5%	8%	10%	5%	8%	10%			
Moisture	11.36±0.40	11.24±0.19	8.25±0.34	8.77±0.16	8.27±0.09	8.13±0.22	8.78±0.12	8.58±0.14	Max, 12
Ash	5.93±0.03	5.71±0.02	5.93±0.01	5.81±0.12	5.85±0.06	6.04±0.03	6.21±0.03	7.79±0.04	-
Crude fat	5.17±0.001	7.82±0.001	10.01±0.005	5.17±0.007	8.44±0.002	9.41±0.005	0.86±0.001	3.89±0.003	Min, 5
Crude protein	33.46±0.04	33.66±0.13	33.11±0.17	32.91±0.07	33.10±0.03	33.44±0.06	33.34±0.02	37.07±0.03	Min, 30
Crude fibre	3.92±1.04	3.86±0.22	2.49±0.81	2.58±0.60	3.13±0.22	3.75±0.75	2.17±0.49	1.79±1.31	Max, 8
Energy (cal g ⁻¹)	4 242±8.9	4 295±7.6	4 241±20.1	4 214±24.9	4 223 ±6.4	4 186±15.1	4 056±6.5	4 164±64.1	-

Note: CNT - control diet; COM - commercial diet; CPO - diet containing crude palm oil; MPOB-HIE - diet containing emulsified palm fatty acid distillates.

Source: *Malaysian Standard (2013).

TABLE 4. PROXIMATE COMPOSITION OF TILAPIA GROWER FISH FEED

Proximate analysis (%)	MPOB-HIE			CPO			CNT	COM	Standard specification*
	5%	8%	10%	5%	8%	10%			
Moisture	10.88±0.26	14.75±0.16	10.43±0.16	10.61±0.19	10.52±0.27	10.14±0.13	10.59±0.30	6.95±0.29	Max, 12
Ash	5.74±0.01	5.29±0.02	5.85±0.01	5.63±0.02	5.74±0.01	5.81±0.02	6.24±0.01	8.74±0.01	-
Crude fat	5.74±0.009	8.92±0.006	9.66±0.002	5.18±0.002	7.62±0.002	9.22±0.002	0.47±0.003	3.60±0.000	Min, 5
Crude protein	31.25±0.13	30.61±0.16	31.14±0.11	31.03±0.04	31.33±0.23	31.76±0.16	32.20±0.11	31.32±0.12	Min, 25
Crude fibre	3.76±0.17	3.96±0.12	2.83±0.21	3.09±0.14	3.53±0.13	4.23±0.55	3.91±0.20	3.28±0.43	Max, 8
Energy (cal g ⁻¹)	4 068±38.6	4 210±19.7	4 011±23.6	4 099±6.6	4 223±29.0	3 802±37.5	3 926±37.4	3 239±20.3	-

Note: CNT - control diet; COM - commercial diet; CPO - diet containing crude palm oil; MPOB-HIE - diet containing emulsified palm fatty acid distillates.

Source: *Malaysian Standard (2013).

Sensory Evaluation

Thirty panellists were recruited from the staff of the Malaysian Palm Oil Board (MPOB) and students. The panellists have been introduced to basic knowledge about sensory evaluation and have been screened for the thresholds of four basic tastes - sweet, salty, sour and bitter. Smell test to identify common flavour related to oils and fats was also carried out to determine their smell sensitiveness. The finalists of the panellists were all with a passing mark of more than 75%. During the sensory evaluation, each panellist was asked to evaluate five steamed fish fillet samples at one time using a quantitative descriptive analysis method.

Sensory evaluation was carried out at the Sensory Laboratory, MPOB Bangi, Selangor, Malaysia (Figure 2). Tilapia fillets fed 5%, 8% and 10% MPOB-HIE and 5%, 8% and 10% CPO feed diets were compared against fillet from tilapia fed COM and CNT feed diets. The evaluation was based on six attributes, namely colour, texture (firmness and sliminess), aroma, taste and overall quality, using a nine-point hedonic scale. Scale 1 indicates the least preferable score, while nine indicates the

highest or most acceptable score. The fish fillets were trimmed from the belly to the tail, cut into 3.8 cm-5.1 cm (1.5-2.0 in) cubes and steamed for 3 min before serving to the panellist. The fish fillet samples were individually blind-coded, labelled in three digits and placed on a clean plate (Figure 3).



Figure 2. Sensory evaluation by the panellists at Sensory Laboratory.

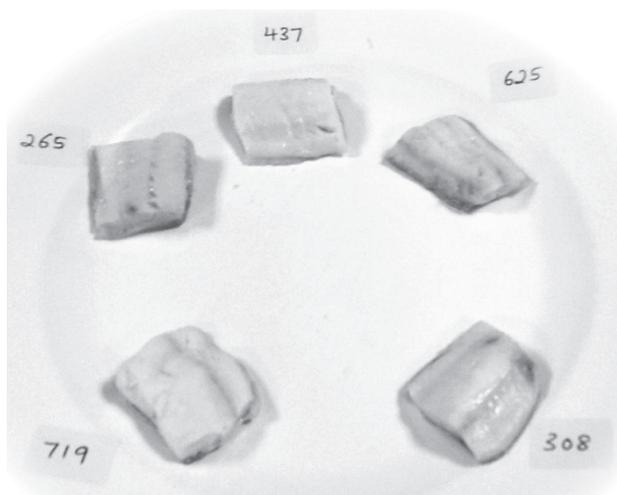


Figure 3. Fish fillet samples with random three digit numbers.

Statistical Analysis

All data collected were subjected to statistical analysis with analysis of variance (ANOVA) and mean differences among treatments were analysed by Duncan's Multiple Range Test using SAS 9.1™ statistical package (SAS Institute Inc. Cary, North Carolina, USA). Differences were considered statistically significant when $p < 0.05$.

RESULTS AND DISCUSSION

The sensory evaluation scores for tilapia fillets fed with MPOB-HIE, CPO, COM and CNT diets are as tabulated in Table 5 and graphically illustrated in Figure 4. There were no significant differences ($P > 0.05$) in all sensory attributes among tilapia fillets fed with different diets. Tilapia fed MPOB-HIE and CPO were fairly accepted by the panellists and were comparable to tilapia fillets fed CNT and COM diets. These results are consistent with Ng and Bahurmiz (2010) since tilapia with various dietary oil sources (fish oil, CPO, PFAD and refined, bleached and deodourised palm oil) has had little effect on sensory attributes. In addition, Ochang *et al.* (2007) conducted a study on the effect of different levels of dietary palm oil on the organoleptic properties of juvenile Nile tilapia. Similar results with our current research have been documented, with no significant differences in the sensory attributes between treatment diets were observed.

In terms of colour, fillet from tilapia fed 5% MPOB-HIE received numerically highest score (mean = 6.43 ± 1.19) as compared with that of the other treatments. According to Nair *et al.* (2017), fish fillet colour plays an important role in a consumer's purchasing decision and fish fillets

TABLE 5. MEANS OF SENSORY ATTRIBUTES OF MPOB-HIE, CPO, COMMERCIAL AND CONTROL TREATMENTS

Attributes	Treatment								P- value
	5% MPOB-HIE	8% MPOB-HIE	10% MPOB-HIE	5% CPO	8% CPO	10% CPO	COM	CNT	
Colour	6.43±1.19	5.60±1.43	5.63±2.24	6.07±1.36	6.07±1.31	5.77±1.70	6.20±1.62	5.72±1.58	0.26
Firmness	5.27±1.68	5.20±1.88	5.10±1.67	5.00±1.68	4.73±1.76	5.07±1.74	5.08±2.01	5.18±1.81	0.97
Sliminess	5.87±1.66	5.70±1.84	5.93±2.05	5.57±2.01	5.33±2.00	5.53±1.68	5.17±1.99	5.62±1.83	0.64
Aroma	5.73±1.62	5.67±1.69	5.53±1.59	5.33±1.52	5.50±1.31	5.70±1.62	5.55±1.71	5.47±1.52	0.98
Taste	6.00±1.62	6.17±1.84	5.70±1.56	5.67±1.65	5.67±1.71	5.80±1.61	5.87±1.69	5.62±1.39	0.85
Overall quality	6.00±1.64	6.07±1.78	5.93±1.70	6.00±1.74	6.00±1.82	5.97±1.47	5.97±1.69	5.77±1.41	0.99

Note: COM - commercial diet; CNT - control diet; CPO - diet containing crude palm oil; MPOB-HIE - diet containing emulsified palm fatty acid distillates.



Figure 4. Sensory evaluation of fillets from tilapia fed diet containing emulsified palm fatty acid distillate (MPOB-HIE), crude palm oil (CPO), control and commercial diets.

that deviate from the typical white flesh colour are less marketable. Fillet of tilapia fed 5% MPOB-HIE also showed the most desirable results in terms of firmness and aroma. The firmness of cooked fish is influenced by the type of fish, but the flesh should look intact, be able to pull out and the meat remain chunky while poking with a fork. According to Ng and Bahurmiz (2010), fish fillets fed with the PFAD diet were considered to be substantially softer than fish fillets fed with the CPO diet, which is contrary to our current study. For aroma attributes, all treatment groups had a mean score ranging from 5.33-5.73, which expressed moderate acceptance towards the smell of fish fillet samples. Ng (2006) reported that supplementation of CPO and PFAD, which are rich in vitamin E in the fish diet, could prevent the production of off-odour and could improve freshness and preserve fish fillets over a longer period of time. With regard to sliminess, fillet of tilapia fed 10% MPOB-HIE diet received the most acceptable score compared to other treatment groups. Meanwhile, fillet of tilapia fed 8% MPOB-HIE received the highest or most desirable taste and overall quality ratings. Our results are consistent with those of Drewnowski and Almiron-Roig (2010) that, apart from providing a dietary energy source for daily consumption, the addition of fat to food may also contribute to human preferences in terms of texture, taste and smell.

CONCLUSION

The findings of this study indicated that palm oil lipids, *i.e.* CPO and MPOB-HIE can be successfully used in fish feed formulations to substitute fish oil dietary without adverse effects on sensory evaluation by the panellists. Considering the availability of oil palm lipid sources at affordable prices, as well as the acceptance of sensory attributes of fish fillets, there is a strong opportunity for the oil palm industry to provide alternative dietary lipid in the aqua feed industry.

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REFERENCES

Abdel-Fattah, M E (2019). *Tilapia Culture*. Second edition. Academic Press. 358 pp.

Babalola, T O and Apata, D F (2012). Effects of dietary lipid source on growth, digestibility and tissue fatty acid composition of *Heterobranchus longifilis* fingerlings. *J. Agriculture Rural Development in the Tropics and Subtropics*, 113(1): 1-11.

Bolivar, R B; Mair, G C and Fitzsimmons, K (2004). New dimensions in farmed tilapia. *Proc. of the Sixth International Symposium on Tilapia in Aquaculture*. Manila, Philippines. p. 241-248.

Bonnie, T Y P and Yusof, M (2009). Characteristic and properties of fatty acid distillates from palm oil. *Oil Palm Bulletin No. 59*: 5-11.

Conte, F; Passantino, A; Long, S and Voslarova, E (2014). Consumers' attitude towards fish meat. *Italian J. Food Safety Vol. 3(3)*: 178-181.

Drewnowski, A and Almiron-Roig, E (2010). Human perceptions and preferences for fat-rich foods. *Fat Detection: Taste, Texture and Post Ingestive Effects* (Montmayeur, J P and Le Coutre, J eds.). Boca Raton (FL): CRC Press/Taylor and Francis. 646 pp.

FAO (2019). Fishery and aquaculture country profiles. Malaysia. FAO Fisheries and Aquaculture Department (online). <http://www.fao.org/fishery>, accessed on 10 April 2020. 8 pp.

Firew, A H; Abebe, G and Mulugeta, W (2019). The process of tilapia feed formulation and implementation in pond aquaculture: Low cost and locally available ingredients option for small-scale farmers. *J. Agriculture and Aquaculture Vol. 1 (2)*: 1-14.

Huss, H H (1995). Quality and quality changes in fresh fish. *FAO Fisheries Technical Paper*. 348 pp.

Loganathan, R; Selvaduray, K R; Radhakrishnan, A and Nesaretnam, K (2009). Palm oil: Rich in health promoting phytonutrients. *Palm Oil Developments No. 50*: 16-25.

Malaysian Standard (2013). MS 2538:2013 *Formulated Fish Feed – Specification*. Department of Standards Malaysia. 7 pp.

Martinsdottir, E; Sveinsdottir, K and Olafsdottir, G (2000). *Development and Implementation of a Computerized Sensory System (QIM) for Fish Freshness*. Project Report CRAFT FAIR FA-S2-9063. p. 18.

Martinsdóttir, E (2002). Quality management of stored fish. *Safety and Quality Issues in Fish Processing* (Bremmer, H A ed.). Woodhead Publishing Limited, United Kingdom. p. 360-378.

- Metro News (2016). Dept. sets high target for tilapia production. <https://www.thestar.com.my/metro/community/2016/06/27/dept-sets-high-target-for-tilapia-production/>, accessed on 10 April 2020.
- Nair, M N; Costa-Lima, B R C; Schilling, M W and Suman, S P (2017). Chapter 10 - Proteomics of color in fresh muscle foods. *Proteomics in Food Science*. DOI:10.1016/B978-0-12-804007-2.00010-2. p. 163-175.
- Nesaretnam, K and Muhammad, B (1993). Nutritional properties of palm oil. *Selected Readings on Palm Oil and its Uses*. PORIM, Bangi. p. 57-67.
- Ng, W K (2004). Palm oil as a novel dietary lipid sources in aquaculture feeds. *Palm Oil Developments No. 41*: 14-18.
- Ng, W K; Wang, Y and Yuen, K H (2004). Tocotrienols from palm oil are more potent antioxidants than dietary α -tocopherol acetate or α -tocopherol succinate for red hybrid tilapia. *Proc. of the Eleventh International Symposium on Nutrition and Feeding in Fish*. Phuket, Thailand. p. 46.
- Ng, W K (2006). Palm oil: Malaysia's gift to the global aquafeed industry. *Asian Aquafeeds: Current Developments in the Aquaculture Feed Industry* (Ng, W K and Ng, C K eds.). Malaysian Fisheries Society Occasional Publication No. 13. p. 40-54.
- Ng, W K; Wang, Y and Yuen, K H (2006). Vitamin E levels in tilapia diets affect fillet quality. <https://www.aquaculturealliance.org/advocate/vitamin-e-levels-in-tilapia-diets-affect-fillet-quality/>, accessed on 12 September 2020. 8 pp.
- Ng, W K and Bahurmiz, O M (2010). Palm oil replaces fish oil in tilapia feed: Substitution also increases shelf life. *Global Aquaculture Advocate, March/April 2010*. p. 69-70.
- Ng, W K; Chong, C Y; Wang, Y and Romano, N (2013). Effects of dietary fish and vegetable oils on the growth, tissue fatty acid composition, oxidative stability and vitamin E content of red hybrid tilapia and efficacy of using fish oil finishing diets. *Aquaculture Vol. 372-375*: 97-110.
- Ochang, S N; Fagbenro, O and Adebayo, O T (2007). Influence of dietary palm oil on growth response, carcass composition, haematology and organoleptic properties of juvenile Nile Tilapia, *Oreochromis niloticus*. *Pakistan J. Nutrition*, 6(5): 424-429.
- Osman, A; Farah Nurshahida, M S and Jumardi, R (2009). MPOB-HIE as a high energy fat supplement for lactating dairy cows. *MPOB Information Series No. 439*: 2 pp.
- Paul, A K; Rahman, M M; Rahman, M M and Islam, M S (2018). Effects of commercial feeds on the growth and carcass compositions of monosex tilapia (*Oreochromis niloticus*). *J. Fisheries Aquatic and Science*, 13: 1-11.
- Wang, M and Lu, M (2016). Tilapia polyculture: A global review. *Aquaculture Research*, 47(8): 2363-2374.
- Wan Nooraida, W M and Abidah, M N (2020). Effects of pellet supplemented with different percentages of oil palm lipid sources on broiler performance, carcass trait and feed quality. *J. Oil Palm Res. Vol. 32(2)*: 313-325.
- Yusoff, A (2015). Status of resource management and aquaculture in Malaysia. *Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia: Challenges in Responsible Production of Aquatic Species. Proc. of the International Workshop on Resource Enhancement and Sustainable Aquaculture Practices in Southeast Asia 2014 (RESA)* (Romana-Eguia, M R R; Parado-Estepa, F D; Salayo, N D and Lebata-Ramos M J H eds.). Aquaculture Dept., Southeast Asian Fisheries Development Centre, Tigbauan, Iloilo, Philippines. p. 53-65.