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Quality of fish fillet from pond-raised red tilapia and its utilisation in the development of value-added product

(Kualiti filet tilapia kolam tanah dan penggunaannya untuk pembangunan produk tambah nilai)

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Keywords: tilapia fillet, tilapia quality, muddy flavour, value-added product

Abstract

The eating quality, fillet yield, protein and fat contents of pond-raised red tilapia were evaluated. The effects of water depuration process on the removal of muddy taste and the development of a value-added product were also studied. The skin-on fillet yield ranged 32–33% while the protein and fat contents of the fillets ranged 16–17% and 1–4% respectively. The fillet yield and protein content were not significantly ($p > 0.05$) affected by the types of feed. However, the fat content of tilapia fed with the commercial feed and traditional feed were significantly higher ($p < 0.05$) than those fed on formulated feeds with and without vitamin E. No depuration was required for fish fed with formulated feeds. Fish fed on commercial and traditional feed need at least 8 h of water depuration process to leach out the muddy taste and increase their acceptability. Geosmin was not detected in all samples. Tilapia fillet battered with tempura battermix comprising 62% wheat flour, 30% corn starch and 8% rice flour was the most acceptable.

Introduction

The term 'off-flavour' in freshwater fish is used to describe the objectionable flavour due to the accumulation of odorous compounds within the fish tissue produced from biological origins (Smith et al. 2008). It is estimated that over 30% of the potential revenue from catfish industry in the United States of America is lost from off-flavour contamination (Eagle et al. 1995).

The problem of off-flavours in the catfish industry in the United States of America has been studied by many researchers (Johnsen and Lyold 1992; Lorio et al. 1992; Johnsen and Dionigi 1994; Johnsen and Bett 1996; Johnsen et al. 1996). The compounds responsible for this problem were reported to be geosmin and 2-methylisoborneol (MIB) produced by bacteria, actinomycetes and blue-green algae such as Oscillatoria (Johnsen and Bett 1996; Johnsen et al. 1996).

An 'earthy/musty' off-flavour was attributed to MIB while an 'earthy/rotten wood' off-flavour was attributed to geosmin. Fish can rapidly absorb these compounds

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through their gills and other tissues exposed to water (Johnsen and Dionigi 1994). Uptake of off-flavour metabolites increases as the water temperature and fat content of the fish increase. The production of off-flavour compounds such as geosmin is affected by temperature and oxygen concentration. Dionigi and Ingram (1994) reported that *Streptomyces tendae* produced more geosmin at 30 °C and 45 °C compared to that at lower temperatures. Off-flavour in tilapia is particularly problematic to the aquaculture industry especially to processors of tilapia products such as battered tilapia fillet, breaded tilapia fillet and tilapia frankfurters (Che Rohani et al. 2004).

Several measures have been taken by the government of Malaysia to increase fish production in the country including the development of the aquaculture sector (Anon. 2004). A total of 21,507 fish farmers and culturists were involved in the aquaculture industry in 2004 and they contributed to the total aquacultured fish production of more than 200,000 tonnes. More than 17,000 of them were involved in the freshwater sector which contributed 27.5% of the total aquaculture production in that year. Red tilapia remain the most popular cultured species for freshwater aquaculture with total landing of approximately 17,000 tonnes in 2004.

Studies on quality issues affecting consumer acceptance of the freshwater fishes are required to boost the industry and increase demand for these fish. Local fish growers have to maintain the quality of their harvest to ensure only on-flavour fish are distributed in the market. A reliable and less expensive method to detect off-flavour in freshwater fish has to be used to capture the market and increase consumer acceptance towards freshwater fish.

A study was conducted to evaluate the quality of tilapia fillet from pond-raised red tilapia. The effect of water depuration process on the muddy flavour and eating quality was also examined. To increase the utilization of tilapia, a study was also conducted to develop a new value-added product from pond-raised tilapia.

Materials and methods

Red tilapia was cultured in farmers' fish ponds in Kuala Krai, Kelantan. Each pond was 12 m x 24 m in size, equipped with an inlet and an outlet water supply. A total of 1,000 tilapia fingerlings, about 25 g each in weight, were released to each pond.

Four types of feed were used in this study. These were commercial feed coded as D, produced by a major local feed supplier in the country, Department of Fisheries (DOF) formulated feed coded as C, DOF formulated feed plus vitamin E coded as E and traditional feeds practised by the farmers consisting of commercial feed plus chicken skin which was coded as T.

Protein and fat contents (dry basis) were 27% and 3.1% for commercial feed (D), 38.4% and 7.3% for formulated feed (C), and 40.5% and 4.3% for formulated feed plus vitamin E (E) respectively. Each treatment was replicated three times. The fish were harvested after 4 months in the grow-out ponds when the size reached 400 g or larger.

Preparation of fish fillet

About 260–300 kg fish was harvested from each pond and divided into 50 kg lots consisting of 90–110 fish. One lot was slaughtered and filleted to determine the fillet yield and proximate compositions. Other lots of fish were subjected to the depuration process in clean water for 0, 8 and 24 h immediately upon harvest prior to filleting.

Depuration tanks were filled with clean water in the ratio of one part live fish to four parts water and equipped with air aspirators, inlet and outlet water supply. The water was changed every 8 h during this process. After the depuration process, the fish were slaughtered, filleted and cleaned. Cleaned fillet was iced and brought to the laboratory in MARDI Kuala Terengganu for quality evaluation.

Development of value-added product

The fish samples used in this study were pooled from the three ponds coded as D (fed with commercial feed) and were subjected to 24 h depuration process before being iced and filleted after rigor. Each fillet was skinned using a skinning machine, cleaned and portioned into small cutlets of 25–30 g pieces.

The cutlets were coated with the batter developed in this study, flash-fried in palm oil at 200 °C for 20 sec before being blast-frozen at –35 °C to a core temperature of –20 °C. The product was then packed in HDPE trays with clear lids, shrink-wrapped and kept frozen at –20 °C in a commercial cold room for further evaluation. Samples were taken out and allowed to thaw at room temperature for 30 min before deep-frying at 170 °C for 3 min and served warm for sensory evaluation.

The batter mix was developed using a simplex lattice design for a mixture system with three types of flour namely wheat flour (X1), corn starch mixture (X2) (equal amount of corn starch and modified starch) and rice flour (X3) in the formulation (Scheffe 1965; Hu 1999). Other ingredients namely water, egg white, leavening agent, spices, salt and food gum were kept at constant level in all formulations. The experiment was replicated twice.

Quality evaluation

Chemical analysis Samples of the fish fillets were analysed for protein, fat, moisture and geosmin contents. The moisture, protein and fat contents of all samples were analysed using AOAC methods (1990).

For the determination of geosmin, analysis was done using gas chromatography mass-spectrum according to the method of Hsieh et al. (1988). A total of 30 g sample was extracted for 4 h using simultaneous distillation extraction (SDE) and the volatiles were collected in dichloromethane. The extract was then dried with anhydrous sodium sulphate and subjected to concentration. The extract (3 µl) was injected into gas chromatograph (HP Model 5890 II GC instrument) coupled directly to a mass spectral detector (HP Model 5971). A bonded phase fused silica capillary column (HP 1, 60 m x 2.5 mm x 0.25 µm) was used.

Operating conditions: Injector and detector temperatures were 220 °C and 280 °C respectively; oven temperature was initially kept at 110 °C for 1 min and then programmed to 270 °C for 10 min at the rate of 8 °C per min; mass transfer line temperature was 280 °C; helium carrier gas flow rate was 1.0 ml/min. For the identification of geosmin (Sigma G5908), 0.5 µl of 2 mg/ml standard solution was injected (Detection limit = 1 µg).

Sensory evaluation The tilapia fillets were subjected to sensory evaluation. The sensory responses of samples were evaluated by a trained panel (n = 17) using a 5-inch horizontal line labelled at both ends and panellists indicated their perception by marking a slash on the line provided for each attribute (Stone et al. 1974; Che Rohani et al. 2000). Portions of cut fillet, about 30 g, were placed into a covered glass container, steamed for 10 min and served warm to panellists.

The attributes evaluated were off-flavour intensity (0 = nil, 1 = strong), taste and overall acceptability (0 = dislike very much, 5 = like very much). The panellists have been trained to detect the muddy flavour in a 3-h training session, conducted a week before the sensory evaluation commenced. Solutions of pure geosmin and methylisoborneol (Sigma), the compounds responsible for the muddy flavour in freshwater fishes, were used to spike the fish samples used in this training session (Johnsen and Llyold 992).

Battered tilapia fillet cutlets were subjected to sensory evaluation after three months storage at –20 ºC during which the samples were subjected to 6 freeze-thaw cycles. Samples were deep-fried and served warm to panellists for evaluation. The panellists evaluated for overall acceptability using a 5-inch horizontal line labelled at both ends and indicated their perception by marking a slash on the line provided to identify their responses. They were instructed to score their overall acceptability based on texture, uniformity, colour, taste and oiliness of the coating as well as off-flavour intensity.

Experimental design and data analysis

Fish In experiment with feed type, a randomized complete block design was adopted with three replicates where each replicate was conducted in 2 weeks apart. Each replicate consisted of four experimental ponds where each feed type was randomly assigned. A total of 12 ponds were used. At each harvesting schedule, fish from each type of feed were harvested.

Raw fillet quality The experimental design used was a 4 x 3 factorial, laid out in a split-plot with three replicates, using four feed types as the main-plot treatments and three depuration times (0, 8 and 24 h) as the sub-plot treatments. At each harvest schedule, fish harvested from each type of feed was split into three lots and each of the depuration time was randomly assigned to each lot.

Value-added product from tilapia fillet Tilapia fillet was coated with different samples of batter mix formulated from three-mixture components according to simplex-lattice design. Each formulation was replicated twice. In each mixture, the proportion of each ingredient was varied from 0.50–1.00 for X1, 0–0.50 for X2 and 0–0.50 for X3 where the proportional ingredients summed to one (X1 + X2 + X3 = 1.0). This technique was used to fit a quadratic canonical polynomial model described by Scheffe (1965) as follows:

$$Yi = b1X1 + b2X2 + b3X3 + b12X1X2 + b13X1X3 + b23X2X3$$

where, b1, b2, b3, b12, b13 and b23 are regression coefficients and X1, X2 and X3 are proportions of wheat flour, mixture of native plus modified corn starch and rice flour respectively.

The intercept and parameters X1X1, X2X2 and X3X3 were set to zero and thus not included in the model.

All data were subjected to statistical analysis using SAS V9.1 (SAS Inst. 2001).

Results and discussion

Quality of raw fillet

The moisture, protein and fat contents of the tilapia fillets from cultured fish fed on four types of feed ranged from 78–81%, 16–17% and 1–4% respectively (*Table 1*). The protein content was not significantly affected ($p > 0.05$) by the types of feed. However, the fat content in fish fed on commercial feed (D) and traditional feed (T) was significantly higher than those fed on formulated feed, with (E) or without additional vitamin E (C).

This observation was probably related to the high protein content in the formulated feeds. Many studies with rats and catfish showed that subjects on high protein diet had lower fat deposition compared to subjects on standard diet (Giri et al. 2003; Blouet et al. 2006). Both formulated feeds (C and E) contained higher protein and fat contents as compared to the commercial feed (D). *Table 1* also showed that tilapia is not a fatty fish and provides a good source of protein.

The fillet yield was not affected by the different types of feed (*Table 1*). The average yield for skin-on fillet was 32–33%. Webster et al. (1993) also reported that the protein content in channel catfish fed on different diets containing 0–30% distillers' grains was not affected by the fish diets.

The effect of the feed types and depuration process on the eating quality of tilapia fillets is shown in *Table 2*. Samples from all four feed treatments were accepted by the taste panel. However, the samples from fish fed on commercial and traditional

Table 1. Proximate composition and yield of red tilapia fillet fed on different types of feed (n = 12)

Types of feed	Composition (g/100 g)			Fillet yield (%) (skin-on)
	Moisture	Protein	Fat	
C	80.5 ± 1.2a	16.9 ± 1.2a	0.9 ± 0.2b	31.7 ± 2.4a
D	79.1 ± 1.4ab	16.5 ± 0.7a	3.1 ± 1.3a	31.9 ± 2.7a
E	81.3 ± 0.9a	16.4 ± 0.7a	0.8 ± 0.4b	33.0 ± 2.4a
T	77.8 ± 2.1b	16.2 ± 1.1a	4.3 ± 1.4a	32.5 ± 2.7a

Means in a column with the same letter are not significantly different at $p > 0.05$
C = Feed formulated by Department of Fisheries, D = Commercial feed,
E = Feed formulated by the Department with added vitamin E,
T = Traditional feed practised by farmers consisting of chicken processing waste and commercial feed

Table 2. Effect of feed types and depuration hours on sensory responses

Sensory attributes	Depuration hours	Types of feed/sensory scores			
		C	D	E	T
Taste	0	4.51a	3.21a	4.49a	3.24a
(0 = dislike very much,	8	4.44a	4.45b	4.47a	4.44ab
5 = like very much)	24	4.58a	4.43b	4.53a	4.55 b
Off-flavour intensity	0	0.38a	0.68a	0.38a	0.56a
(0 = nil,	8	0.41a	0.41b	0.39a	0.33ab
1 = very strong)	24	0.34a	0.37b	0.37a	0.28b
Overall acceptance	0	4.49a	3.19a	4.50a	3.21a
(0 = dislike very much,	8	4.42a	4.42b	4.47a	4.45b
5 = like very much)	24	4.53a	4.47b	4.50a	4.54b

Each mean was calculated from 612 observation
Means are calculated from panellist responses (n = 17) for each attribute. Means in a column followed by the same letter are not significantly different ($p > 0.05$) from each other
C = Feed formulated by Department of Fisheries, D = Commercial feed,
E = Feed formulated by the Department with added vitamin E,
T = Traditional feed practised by farmers consisting of chicken processing waste and commercial feed

feeds received significantly lower scores for taste and overall acceptability ($p < 0.05$) if the fish were not subjected to water depuration process before slaughtering. The scores for off-flavour intensity for both of these samples were also significantly higher ($p < 0.05$).

When the fish were subjected to depuration process for 8 h, the eating quality improved significantly as shown by the significant higher scores for taste and overall acceptability ($p < 0.05$) of these samples. There was also a significant interaction ($p < 0.05$) between feed types and depuration hours on taste, off-flavour intensity and overall acceptability. The results clearly showed that water depuration process on live tilapia had effectively leached out the off-flavour compounds from the fish muscle.

The presence of muddy taste in fish fed on commercial and traditional feeds as detected by sensory panel might be related to the higher fat content of 3.1% in fish fed on D feed and 4.3% in fish fed on T feed (*Table 1*). Off-flavour uptake from the water by channel catfish is influenced by the tissue fat content (Johnsen and Lloyd 1992; Dionigi et al. 1998). The higher the fat content, the faster the uptake of MIB by the fish thereby creating a stronger off-flavour intensity detected by the taste panel.

Geosmin, one of the compounds responsible for off-flavour in freshwater fish, was not detected by instrumental analysis using gas chromatography mass-spectrum detector in all the samples. This could be attributed to the fact that the detection level of the instrument used in this study was higher than human threshold sensitivities. Human threshold sensitivities for these compounds are reported to be very low of about 10 ng/litre for geosmin and 30 ng/litre for MIB (Johnsen and Kuan 1987).

The earthy or muddy flavour detected in freshwater fish can occur as a result of many factors. However, most studies in the catfish industry in the United States consider environmental off-flavours associated with blooms of blue-green algae and microbes to be its most significant problem (Bett and Dionigi 1997). Algal blooms can produce geosmin and MIB which impart muddy, musty flavour to freshwater fish. In this study, when algal blooms were observed in some of our experimental ponds, fresh water was circulated into the affected ponds to flush out much of the algae.

Development of value-added product

The taste panellists could still detect the muddy flavour in cooked tilapia even though the fillet was coated with spicy batter. Therefore, only tilapia fillet obtained from the depurated fish was used to develop a new frozen battered product named tilapia tempura. Wheat flour, corn starch and rice flour were used to develop an acceptable leavened coating batter for frozen tilapia tempura.

The overall acceptability scores for the tempura ranged 2.00–4.19 (*Table 3*). The coefficient of determination (R^2) for the best-fitting model equation relating independent and dependent variables was high for overall acceptability ($R^2 = 0.99$). The model equation for this variable is:

$$OA = 2.27*X1 - 2.66*X2 - 2.91*X3 + 15.64*X1*X2 + 15.84*X1*X3 + 4.68*X2*X3$$

where OA = overall acceptability, X1 = wheat flour, X2 = corn starch and X3 = rice flour.

The model equation indicated that the interaction between wheat flour (X1) and corn starch (X2) as well as wheat flour (X1) and rice flour (X3) have binary synergistic effects, that is, the binary blends with wheat flour produced higher overall acceptability scores than would be expected if using wheat flour alone. High protein wheat flour containing 12–14% protein was used to give a satisfactory uniform coating during the battering process. However, wheat flour alone would produce a soggy coating.

Corn starch used was a mixture of equal proportion of native corn starch and

Table 3. Simplex-lattice design for the amount of three types of flour in the batter mix to coat tilapia tempura

Design point	X1 (wheat flour)	X2 (mixture of native plus modified corn starch)	X3 (rice flour)	Scores for overall acceptance (range)
1	1.00	0.00	0.00	2.54, 2.00
2	0.50	0.00	0.50	3.71, 3.57
3	0.50	0.50	0.00	3.82, 3.61
4	0.75	0.00	0.25	3.97, 3.92
5	0.75	0.25	0.00	4.05, 3.89
6	0.50	0.25	0.25	4.19, 3.75

modified corn starch. Modified starch is required to increase the product freeze-thaw stability during frozen storage. Rice flour was found to have a positive effect on the texture of the product as the coating of the product was crispier.

Figure 1 shows the contour plot of the overall acceptability score with respect to flour proportions in the batter mix. The contour plot indicated that batter mix containing 50–62% wheat flour, 28–45% corn starch and 3–10% rice flour produced the most acceptable frozen battered tilapia fillet with the average overall acceptability of more than 4.0.

Verification experiment was conducted using four batter mix blends including the formulations in the optimum region (BT optimum, BT F1, BT F2) and a formulation outside the optimum region (BT F3). *Table 4* shows that the mean scores for crispiness and overall acceptability of the samples prepared using the formulation blend in the optimum regions were significantly higher ($p < 0.05$) than the formulation blend outside the optimum region (BT F3). Batter mix formulations in the optimum region gave uniform coating that bound nicely to the fish fillet even after storage at abuse temperatures. Other formulations produced uneven coating that tend to fall-off after storage.

Conclusion

Pond-raised red tilapia produced a good quality fillet in terms of protein and fat content as well as eating quality. The types of feed used to raise the fish had a significant effect on the flavour of the tilapia fillet. However, the simple water depuration process for 8 h had been proven to be able to leach out the muddy flavour from tilapia fillet and increased its acceptability significantly. Fish fed on experimental formulated feed from Department of Fisheries produced a leaner fillet with better eating quality when compared to fillet from fish fed on commercial feed.

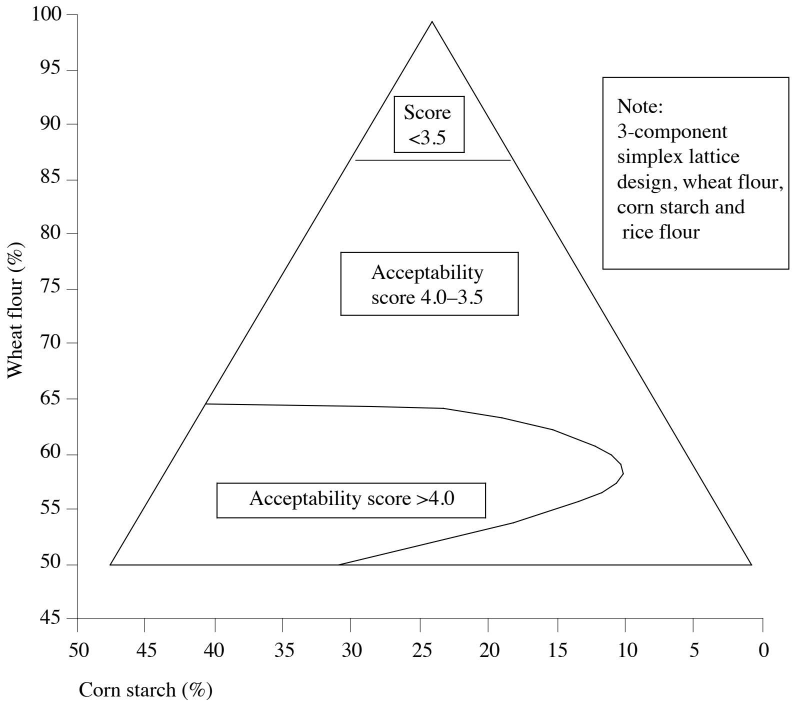

Figure 1. Contour plot of the overall acceptability score of tilapia tempura with respect to the flour proportions in the batter mix

Table 4. Average scores for the sensory attributes of battered tilapia in the verification experiment

Sample code	Crispiness	Overall acceptance
BT Optimum	4.43a	4.34a
BT F1	4.10ab	4.12a
BT F2	4.12ab	4.11a
BT F3	3.38c	3.52b

Means are calculated from panellist responses (n = 24) for each attribute. Means in a column followed by the same letter are not significantly different (p <0.05)

BT Optimum = 62% wheat flour, 30% corn starch and 8% rice flour
BT F1 = 64% wheat flour, 24% corn starch and 12% rice flour
BT F2 = 57% wheat flour, 40% corn starch and 3% rice flour
BT F3 = 88% wheat flour, 10% corn starch and 2% rice flour

Pond-raised tilapia can be used as suitable raw material for down-stream processing of value-added product such as tempura. The batter mix formulation containing 62% wheat flour, 15% native corn starch, 15% modified corn starch and 8% rice flour was the most acceptable for tilapia tempura in terms of taste and frying performance after frozen storage.

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References

Anon. (2004). *Annual fisheries statistics*. Vol. 1. Kuala Lumpur: Department of Fisheries Malaysia

AOAC (1990). *Official methods of analysis*, 15th Ed., Washington DC: Association of Official Analytical Chemists

Bett, K.L. and Dionigi, C.P. (1997). Detecting seafood off-flavors: Limitations of sensory evaluation. *Food Technol*. 51(8): 70–81

Blouet, C., Mariotti, F., Azzout-Marniche, D., Bos, C., Mathe, V., Tome, D. and Huneau, J.F. (2006). The reduced energy intake of rats fed a high-protein low-carbohydrate diet explains the lower fat deposition, but macronutrient substitution accounts for improved glycemic control. *J. Nutr.* 136: 1849–1854

Che Rohani, A., Zahrah, T. and Che Utama, C.M. (2004). Development of tilapia frankfurters using response surface methodology. *J. Trop. Agric. and Fd. Sc*. 32(1): 31–38

Che Rohani, A., Zahrah, T. and Mat Arup, J. (2000). Development of frozen savoury grilled fish (ikan percik). *J. Trop. Agric, and Fd. Sc*. 28(2): 203–219

Dionigi, C.H. and Ingram, D.A. (1994). Effects of temperature and oxygen concentration on geosmin production by *Streptomyces tendae* and *Penicillium expansum*. *J. Agric Food Chem*. 42(1): 143–145

Dionigi, C.P., Bett, K.L., Johnsen, P.B., Mcgillberry, J.H., Millie, D.F. and Vinyard, B.T. (1998). Variation in Channel Catfish *Ictalurus puntatus* flavor quality and its quality control implications. *J. World Aqua. Society* 29(2): 1140–1153

Eagle, C.R., Pounds, G.L. and van der Ploeg, M. (1995). The costs of off-flavour. *J. World Aqua. Soc*. 26: 297–306

Giri, S.S., Sahoo, S.K., Sahu, A.K. and Meher, P.K. (2003). Effect of dietary protein level on growth, survival, feed utilization and body composition of hybrid Clarias catfish (*Clarius batrachus* x *Clarius gariepinus*). *Animal feed Sc. and Tech*. 104: 169–178

Hsieh, T. C-Y., Tanchotikul, U. and Matiella, J.E. (1988). Identification of geosmin as the major muddy off-flavour of Louisiana Balck Water Clam (*Rangia cuneta*). *J Fd. Sci*. 53: 1228–1229

Hu, R. (1999). *Food Product Design: A computer-aided statistical approach*. Pennsylvania

Johnsen, P.B. and Bett, K.L. (1996). Sensory evaluation of the off-flavors geosmin and 2-methylisoborneol (MIB) in farm-raised catfish. *J. App. Aquaculture* 6(2): 21–37

Johnsen, P.B. and Dionigi, C.P. (1994). Physiological approaches to the management of off-flavors in farm-raised Channel Catfish (*Ictalurus puntatus*). *J. Appl. Aquaculture* 3: 141–161

Johnsen, P.B. and Kuan, J-C.W. (1987). Simplified method to quantify geosmin and 2- methylisoborneol concentrations in water and microbiological cultures. *J. Chromatogr.* 409: 337–342

Johnsen, P.B. and Lloyd, S.W. (1992). Influence of fat uptake and depuration of the off-flavour 2-methylisoborneol by Channel Catfish (*Ictalurus puntatus*). *Can. J. Fish Aquat. Sci.* 49: 2406–2411

Johnsen, P.B., Lloyd, S.W., Vinyard, B.T. and Dionigi, C.P. (1996). Effects of temperature on the uptake and depuration of 2-methylisoborneol in Channel Catfish (*Ictalurus puntatus*). *J. World Aqua. Society* 27(1): 15–20

Lorio, W.J., Perschbacher, P.W. and Johnsen, P.B. (1992). Relationship between water quality, phytoplankton community and off-flavors in channel catfish (*Ictalurus punctatus*) production ponds. *Aquaculture* 106: 285–292

SAS Inst. (2001). SAS/STAT. *User's Guide, version 9.1*, Cary, NC: SAS Institute Inc.

Scheffe, H. (1965). The simplex-centroid design for experiments with mixtures. *J. Royal Statistic Soc*. Series B 25: 235

Smith, J.L., Boyer, G.L. and Zimba, P.V. (2008). A review of cyanobacterial odorous and bioactive metabolites: Impacts and management alternatives in aquaculture. *Aquaculture* 280: 5–20

Stone, J., Sidel, J. and Woolsey, A. (1974). Sensory evaluation by quantitative descriptive analysis. *Food Technol*. 28(11): 24–34

Webster, C.D., Tidwell, J.H., Goodgame, L.S. and Johnsen, P.B. (1993). Growth, body composition, and organoleptic evaluation of Channel Catfish fed diets containing different percentages of distillers' grains with solubles. *The Progressive Fish Culturist* 55: 95–100

Abstrak

Kualiti filet, kadar perolehan, kandungan protein serta lemak, dan penerimaan filet ikan tilapia merah yang diternak di dalam kolam tanah telah dinilai. Kesan proses depurasi bagi membuang rasa selut dan pembangunan produk baru juga dikaji. Perolehan filet ialah 32–33% dengan kandungan protein dan lemak masing-masing 16–17% dan 1–4%. Jenis makanan ikan tidak mempunyai kesan signifikan ($p > 0.05$) terhadap kadar perolehan filet dan kandungan protein ikan. Walau bagaimanapun, kandungan lemak filet tilapia yang diberi makanan komersial dan tradisional adalah lebih tinggi secara signifikan ($p < 0.01$) berbanding dengan kandungan lemak filet ikan yang diberi makanan rumusan dengan atau tanpa tambahan vitamin E. Proses depurasi tidak diperlukan untuk ikan yang diberi makanan rumusan Jabatan Perikanan. Ikan yang diberi makan rumusan komersial dan tradisional memerlukan proses depurasi sekurang-kurangnya 8 jam untuk menghilangkan rasa selut dan meningkatkan penerimaan. Geosmin tidak dapat dikesan di dalam semua sampel yang dianalisis termasuk sampel yang dikesan mempunyai rasa selut oleh ahli nilai rasa. Tempura tilapia sejuk beku yang disalut dengan campuran bater tempura yang mengandungi 62% tepung gandum, 30% tepung jagung dan 8% tepung beras ialah yang paling diterima.

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