FRESHWATER FISH

the Overlooked Alternative

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Dedication

Specially for my late father,
My mom,
My husband and
All my children

ABSTRACT

The marine fish supply has been dwindling for the past decades, although it was once thought to be inexhaustible. World capture of fish for food rose dramatically from 1973 to 1997 resulting in over exploitation, which was followed by a subsequent decline in world catch, the contrary world per capita food fish consumption has risen due to the increase in world population. Globally, attempts are being made to address the issues on sustaining the supply of marine fisheries; however, this is still not sufficient to ensure world food security. The domestic fish production in Malaysia for year 2007 was estimated at 1.5 million mt, mainly from marine capture fisheries which accounted for 1.2 million mt and the rest from the aquaculture sector. Malaysia is still a net importer of fish and fishery products. The present scenario of rising food prices and the need to feed the increasing world population, has caused the world to turn to aquaculture, which is said to be the fastest growing food sector in the world food production industry. With the fast growing urban population, the food manufacturing industry has to grow and flourish at the same rate or perhaps faster. The insufficient supply of marine fish, the traditional raw material, is slowly inching into the industry. Hence, to sustain this food manufacturing sector, an alternative raw material supply has to be looked into. This lecture, therefore, tries to examine, from the scientific and technological point of view, the possibilities of freshwater fish being utilized as food, raw material and as an ingredient to support the activities of the food manufacturing industry at large.

Keywords: freshwater fish, aquaculture, food manufacturing industry, alternative ingredient

INTRODUCTION

The supply of fish from the oceans once thought inexhaustible, is no longer true as seen in the last three decades. This could be the result of over exploitation as reflected in the dramatic rise of world capture of fish for food from 1973 to 1997. The growth in the aquaculture sector has attempted to fill the gap between supply and demand (Delgado et al., 2003). The productivity of world fish production is mainly due to the aquaculture sector. People in the developing world continue in their food fish consumption, whereas total consumption in the developed nations will remain static. Under the ecological collapse scenario, consumption will drop from 17.1 to 14.2 kg per year (Delgado et al., 2003).

About one-third of the world catch is not used for direct human consumption but for the production of fishery by-products such as fish meal, fish oil, fish silage, hydrolyzed fish products, fish protein concentrate (FPC), pet food, insulin manufacture and many others (Windsor and Barlow, 1981). In Malaysia, about 40 % of trash fish is converted to fishmeal and 25 % to fertilizers.

Globally, issues on sustaining the supply of marine fisheries for the next decade is actively debated and attempts are being made by all concerned parties to minimize the natural deficit. Several studies have also been carried out and reported, by the Malaysian authorities, concerning the issues of marine catch and landings. Kedah is one of the important states for fisheries on the West coast of Malaysia standing at number three after Perak and Selangor. Analysis of its landings from 1979 to 1994 showed that marine landings in Kedah had dropped by 12%. Recovery periods and maximum landing was obtained in 1982, but subsequently the tonnage of landings never recovered (Alias and Mohd. Saupi, 2000). It was also concluded in the survey that although the landings had shown some increase, the biomass of the target fish species (25 species) for the West coast of Malaysia were declining. Abu Talib et al. (2006) conducted a survey on the impact of Tsunami on demersal fish assemblages off Kedah and Penang waters and concluded that consistent delineation of assemblage groups was observed and there were no difference between pre- and post-tsunami data. However, there appeared to be a varied species composition.

The domestic fish production in Malaysia for year 2007 was estimated at 1.5 million mt, with marine capture fisheries accounting for 1.2 million mt and the rest was from the aquaculture sector (Pawiro, 2008). Malaysia is still a net importer of fishery products catering for local consumption and also the food processing industry. However, black tilapia and Indian mackerel are exported to Belawan port (Medan) through Lumut, Perak (Pawiro, 2008).

The processed-food industry in Malaysia is aided by the fact that the country possesses a diversity of cultures, resulting in an extensive and exotic variety of processed foods. Fish- based food manufacturing is very dependent on the importation of raw materials such as tuna, sardine and surimi for the processing of surimi-based products. They are brought in from Thailand, Vietnam, Indonesia, Myanmar and India. Therefore, to support the growth of our manufacturing sector, an alternative has to be thought of. The scientific information on utililization of freshwater fish for complete or partial substitution of the traditional marine fish is invaluable globally.

WORLD AQUACULTURE PRODUCTION

The present scenario of rising food prices, demand for arable land and sources of water for irrigation and signs of 'food riot' to feed the increasing world population has caused the world to turn to aquaculture, which is said to be the fastest growing food sector in the world food production industry, Subasinghe (2008). It has a special role in ensuring global food security. This is very well depicted in the graph below (Figure 1) where the output from the world aquaculture production escalated around the time of the mid 1980s (FAO, 2006).

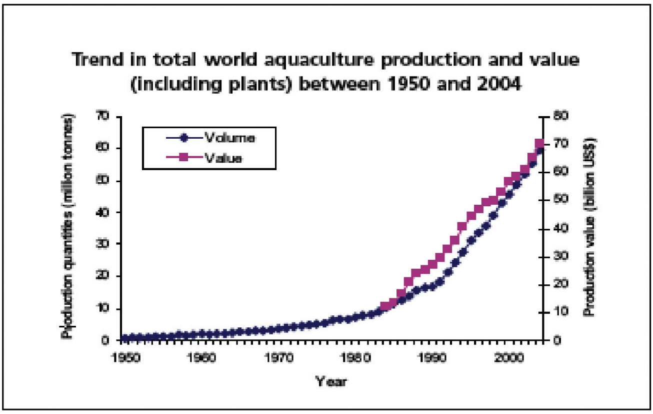


Figure 1 Trends in aquaculture production for the year 1950 – 2004.

Aquaculture Producers of the World

China (Table 1) is the largest producer of aquaculture in the world contributing to 51.2 % of total production value (FAO, 2006). This is followed by Japan (6.0%), India (4.2%) and Chile (4.0%). Philippines, Indonesia, Vietnam and Thailand, are the Malaysian immediate neighboring countries which are among the top ten biggest producers of aquaculture.

Table 1 Top ten aquaculture producers in the world in 2004

Top 10 aquaculture producers in the world in 2004

Country	Production volume (tonnes)	Global (%)	Production value (1 000 US$)	Global (%)
China	41 329 608	69.6	35 997 253	51.2
India	2 472 335	4.2	2 936 478	4.2
Philippines	1 717 028	2.9	794 711	1.1
Indonesia	1 468 612	2.5	2 162 849	3.1
Japan	1 260 810	2.1	4 241 820	6.0
Viet Nam	1 228 617	2.1	2 458 589	3.5
Thailand	1 172 866	2.0	1 586 625	2.3
Korea, Republic of	952 856	1.6	1 211741	1.7
Bangladesh	914 752	1.5	1 363 180	1.9
Chile	694 693	1.2	2 814 837	4.0

Principal Species

Based on the FAO statistics from year 2000 to 2006 (Figure 2), silver carp, grass carp, common carp, caras, tilapia and salmon are the principle species in descending order (FAO, 2006).

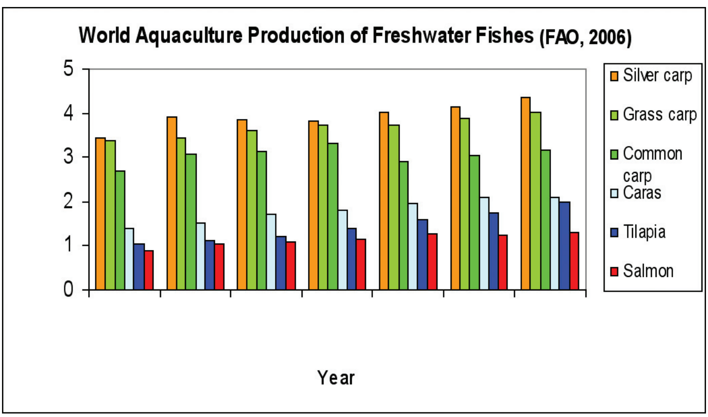


Figure 2 Principle freshwater fish species cultured in 2006

FRESHWATER FISH AS AN ALTERNATIVE

Physico-chemical Properties of Freshwater Fish

Chemical Composition of Fish Muscle

The variation in the chemical composition of fish is closely related to feed intake, migratory swimming and sexual changes in connection with spawning (Shewan, 1974). The principal constituents of fish muscle can be divided into protein, lipid, carbohydrate, ash and water. Water is the biggest component and normally it is inversely related to the lipid content of the fish muscle. Variation within a species can exist due to seasonal variation, gender, water environment and feed. Jamilah and Nurul (1995) reported that the farmed catfish (*Clarias batrichus*, Linnaeus) and red tilapia (*Oreochromis* sp.) had moisture content of 74.5 and 77.2 %, respectively. Their fat contents were 2.2 and 1.6 %, respectively. However, work carried out in 1996, indicated that the fat content in catfish was approximately 19.8 % and that of red tilapia was 2.5% (Ismail, 1996). This great variation was most probably due to the nature of the feed since the catfish was cultured. The lipid fraction is the most variable component. Not only the total lipid but also the lipid composition is important for the food processing sector since this will affect ease of handling prior to processing and will also dictate the stability of the fish muscle for any processing application.

The non protein nitrogen (NPN) fraction in fish also varies from species to species, but also within the species depending on size, season and muscle sample. An example of the distribution of the different compounds in the NPN-fraction in freshwater and marine fish is shown in Figure 3.

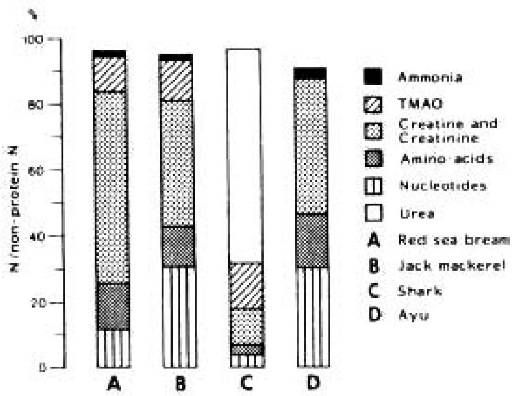


Figure 3 Distribution of non-protein nitrogen in fish muscles of two marine bonyfish (A,B), an elasmobranch (C), and a freshwater fish (D) (Konosu and Yamaguchi, 1982; Suyama *et al.,* 1977)

Acceptance of Freshwater Fish as Food and as Material for Food Processing

Geosmin and 2-methylisoborneol (MIB) are semi-volatile terpenoid compounds produced as secondary metabolites by benthic and planktonic cyanobacteria, several genera of fungi and various actinomycetes. These off-flavor compounds posed a heavy economic burden in the aquaculture industry rendering fish unmarketable unless purified by purging with large quantities of clean water (Guttman and Jaap van Rijn, 2008).

Muddy Flavor and Odor

The source of earthy odour and flavour in fish was reported as early as in 1936. Further research has shown that the earthy compounds, geosmin and methylisoborneol are major contributors to the muddy flavor in fish. The occurrence of these compounds had a very close relationship with blue-green algae blooms and the presence of actinomycetes in water. Earthy flavour in fish may arise via many routes. During those off-flavour episodes, which occur when water temperature is high, fish flesh becomes unpalatable and thus has low market value (Persson, 1982; Sivonen, 1982). Early studies by Thayssen and Pentelow (1936) found that the earthy taint principally permeated from the water into the flesh of the fish through its gills. In 1984, From et al. studied sites of geosmin uptake in rainbow trout (*Salmi gairnderi*) and suggested that fish could acquire the earthy-flavour through ingested water as well as through the gills. The skin could also be a site of absorption. From their studies, they identified the major sites of geosmin uptake in rainbow trout whereby the most rapid absorption occurred in the gills (6 min), followed by the skin (1.5 hr), small intestine (4 hr) and stomach (7 hr). One of other possible routes of the development of musty or earthy aroma in marine fresh fish is through the growth of *Pseudomonas perolens* during refrigerated storage. These organisms are able to produce 2-methoxy-3-sec-butylpyrazine and 2-methoxy-3-isopropylpyrazine which have potent musty and potato-like odours (Maga, 1987). The earthy taste in fish is usually distinct and there are several descriptive terms which are definitely connected with this type of off-flavour which are mud-like, rotten, decayed, mouldy and algal (Kuusi and Suihko ,1983).

Muddy odor in freshwater fish is caused by compounds absorbed from water through the gills or the skin (Lovell and Sackey, 1973; From and Hrlyck, 1984). Channel catfish production is the largest component of freshwater aquaculture in the United States and the fish production has increased by 153% over the past 10 years (Zimba and Grimm, 2003). In 2000, Zimba and Grimm, (2003) conducted a survey on 485 ponds and found that MIB and/or geosmin off-flavors occurred in 25% of the samples and concluded that the off-flavor compounds (geosmin and MIB) were correlated to a lesser degree with zeaxanthin production (r=0.78), whereas aphanizyphyl was better correlated with MIB and geosmin (r=0.89 and 0.56, respectively), again suggesting cyanobacterial production of these compounds. Guttman and Jaap van Rijn, (2008) studied the production of these compounds in tilapia cultured in recirculated pond systems and concluded that aerobic, organic-rich conditions stimulate the growth of actinomycetes and subsequent production of geosmin and MIB in the system.

Nurul et al. (2004) reported traces of geosmin and isoborneol in the volatile compounds isolated from freshly caught black tilapia (*Oreochromis mossambica*) from ex-tin mines used as culture ponds.

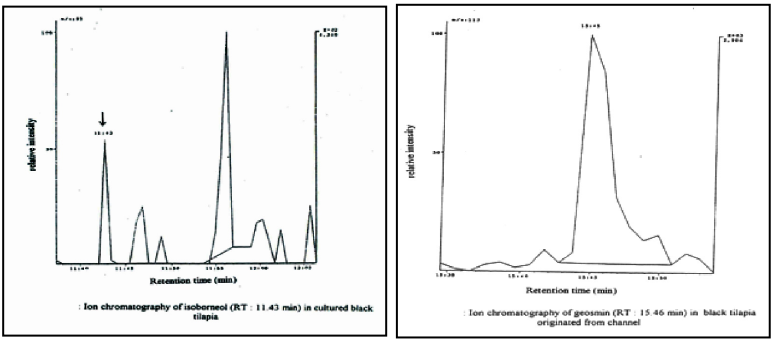
Earthy Flavor Components

Several chemicals have been implicated for the earthy character, such as unsaturated γ-lactones, sesquiterpenoids (cadin-4-ene-ol), mucidone (6-ethyl-3-isobutyl-2-pyrone) and selina-4(14),7(11)-diene-9-ol. Specifically, the components most often responsible for the earthy defect in fish are geosmin (Yurkowski and Tabachek, 1974) and 2-methylisoborneol (Martin et al 1987). These components are very potent and minute traces may produce an earthy-musty character in water as well as in fish (Hofer, 1998). Reasonable values of detection thresholds of geosmin and MIB in water are 0.015 and 0.035 μg l^{-1}, respectively. Their detection thresholds in fish are affected by the lipid content of the fish (Howgate, 2003**).**
Geosmin and 2-methylisoborneol (MIB) are semi-volatile terpenoid compounds produced as secondary metabolites by benthic and planktonic cyanobacteria, several genera of fungi and various actinomycetes (Guttman and Jaap van Rijn, 2008).

Geosmin

Geosmin (*trans*-1,10-dimethyl-*trans*-9-decalol) is a tertiary alcohol compound that is best known for its musty or earthy smell. The isomeric forms of geosmin which had an overpowering pungent musty/earthy property were the *cis/trans* and *trans/trans* isomeric, while isomers of *trans/cis* and *cis/cis* had only a background of earthy aroma but were primarily reminiscent of camphor and cedar (Maga, 1987). According to Gerber (1983), 'ge' from the Greek means earth and 'osme' meaning odour. The most dominant metabolites are geosmine and methylisoborneol (MIB), for which the structural formulas given in threshold levels for geosmine are in the order of 10–20 ng/l giving an earthy odour (in water). Nurul Izzah et al.(2004) reported the identification of geosmin and isoborneol in tilapia caught in an ex-mining pool, the river flowing through the area within the campus vicinity and the lake near a residential area and found that the amounts of these two compounds varied. The detection of geosmin and isoborneol were confirmed by their retention times and their expected molecular ion peak and base peaks (Nurul Izzah et al., 2004). Figure 4 shows the chromatograms of their retention times [(a)-isoborneol at 11.4 min; (b) – geosmin at 15.46 min]

The more stagnant the water, the higher the concentration (Nurul Izzah et al., 2000). Forty-six compounds were positively identified consisting of cyclic and hydrocarbon, ketones, aromatic compounds, aldehydes, N- and S- containing compounds and ester. Alcohol, acid and furan were detected as minor compounds. Below are two of the chromatograms obtained during the identification of the two compounds (Figure 5)



(a) (b)

Figure 4 Ion chromatography of (a) isoborneal and (b) geosmin in cultured black tilapia

(a)

(b)

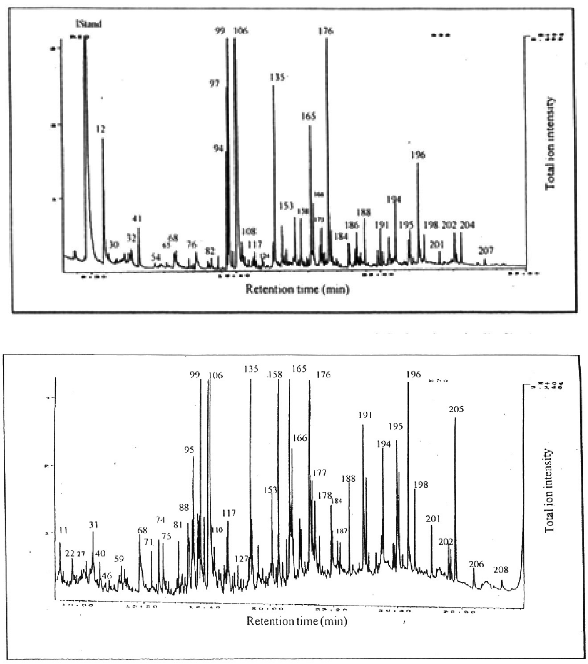


Figure 5 The total ion chromatograms of volatiles (a) cultured and (b) lake origin black tilapia

Aroma, flavour and aftertaste profiles of cooked muscle of marine and freshwater fish were reported and the sensory scores for aroma are as shown in Table 2 (Jamilah et al., 2001).

Table 2 The description and the sensory scores for aroma in cooked muscle of Indian mackerel, bonito, catfish and tilapia

Description	Indian mackerel	bonito	catfish	tilapia
1. Briny	4	4	3	3
2. Blood	2	4	NR**	NR**
3. Earthy	NR**	2	3	5
4. Fish oil	6	7	6	5
5. Fresh fish	5	4	5	5
6. Musty	NR**	NR**	3	3
7. Scorched	NR**	6	3	NR**
8. Smoked	NR**	NR**	3	3
9. Sour	5	7	5	6
10. Sweet	5	4	5	6

*scores of 1 =light; 4 – moderate and 7 – strong
** NR – not recognized
Scores are average of 5 evaluations

The study was carried out using trained panelists to identify the differences in aroma, flavor and the aftertaste characteristics of a few commonly consumed fish in Malaysia. The identified individual flavor profile of the fish used are not the same (Jamilah et al., 2001) and thus support the earlier findings that each fish has its own unique flavor characteristics which is mainly attributable to the presence of specific components, recognition of the threshold value and their concentration (Josephson, 1991).

Methods for Removal of Muddy Favor and Odor

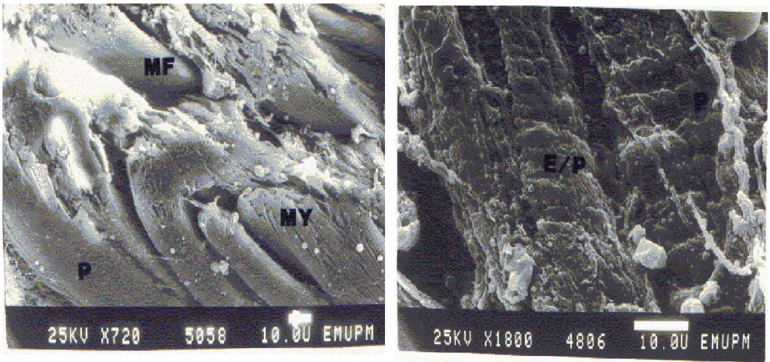
The recommendations for the removal of muddy odour and flavour have been numerous and most of the methods recommended were for live fish. Some are merely good management of the holding areas for the cultured fish, holding live fish from up to several days to over a week, while some reported chemical washing treatments or depuration practices which are more practical for the manufacturing industries. The traditional household practice in Malaysia is to use either tamarind or lime juice to decrease these off-flavors and odors. Mohsin et al. (1999) reported that washing with banana leaf ash at 5% ash with a soaking time of 5 min was acceptable for eating.

Shelf Life of Freshwater Fish

In the 1970s and up to the early 2000s, active works on the spoilage patterns of freshwater fish were carried out. This was when freshwater fish was put into the picture of food science and technology as a potentially good protein source for poor and developing nations in particular, and not so much as a raw material for the food manufacturing industry. The concern was whether the spoilage pattern of freshwater fish resembled that of marine fish and whether those from the temperate were similar to tropical freshwater fish.

Research was also carried out on the microbial and biochemical indices for the purpose of identifying the differences in the pattern of biochemical changes between freshwater and marine fish. These findings were used for the development of the database for the preparation of relevant guidelines and good handling practices both by local and the foreign authorities (Jamilah et al., 1990). This spoilage pattern could also be seen from the changes in the microstructure of the fish muscle. Figure 6 shows the microstructure of bighead carp muscle and it is evident from the micrographs that the changes are the same as in marine fish, although, not at the same rate when considering temperature responses (Jamilah, 2004).

Reports on tropical freshwater fish were negligible at that time. Bighead carp (common carp), pangasius (*patin*) and catfish (*Clarias* sp) were some of the common tropical freshwater fish found and cultured in Malaysia during those periods. Fillets of *Pangasius sutchi,* which were prepared from live and immediately sacrificed fish, were kept on ice for 18 days. The fillets were found to be acceptable for only up to the 8th day of storage (Jamilah et al., 1990). Bighead carp was reported to be acceptable for up to 12 hr at ambient temperature, which corresponded to a TBARS value of 4.2 to 0.5 umol malonaldehyde/kg and a TVN value of 5.32 mg N per 100g (Jamilah and Mohd Yusop, 1993). The sensory, biochemical and microbiological changes of farmed catfish (*Clarias batrachus*, Linnaeus) and red tilapia (*Oreochromis* sp.) at ambient storage were reported, whereby they did not exhibit the same shelf life and changes in chemical indices evaluated. For farmed catfish (*Clarias batrachus*, Linnaeus) and red tilapia (*Oreochromis* sp.) the storage periods were 20 and 15 h, respectively (Jamilah and Nurul Izzah, 1995). In conclusion, the shelf life of freshwater fish was not distinctly different from marine fish.



(a) (b)

Figure 6 Electron microscopy of bighead carp (a) normal muscle and (b) muscle in rigor

Freshwater Fish as Food and Its Consumption

Fish has been increasingly recognized as a healthy source of protein and 80% of the global fishery imports in 2006 are by the developed world (Ferdouse, 2008). This pattern of consumption is quite different from about a decade ago where freshwater fish consumption was more to cater for the eradication of hunger in poorer nations. As evident in Figure 7, freshwater fish was displayed for sale in a wet market in Holland in 2008. The global production for the year 2006, 42% was contributed by aquaculture and 58% by capture fishery. Farmed *pangasius* and tilapia from Asia have successfully penetrated the fish fillets markets in Europe and in United States (Ferdouse, 2008) with the supply being mainly from China, Thailand, Indonesia and Vietnam.

Figure 7 Fresh freshwater fish displayed for sale in the wet market in Hague, Holland.

According to the FAO (1999a), the amount of food fish consumed on a global scale has increased from 45 mmt in 1973 to over 90 mmt in 1997. Over this span, world per capita food fish consumption has also risen from 12 kg/year to 16 kg/year. These increases have not been uniform across geographic or economic categories. Growth in food fish consumption has primarily been a developing-country phenomenon (Delgado et al.,2003). The FAO commodity group showing the most rapid increases in consumption over the past several years has been 'freshwater and diadromous fishes'. This grouping contains freshwater fish, such as carp, as well as diadromous fish (fish that migrate between fresh and saltwater), such as salmon. Consumption of both types of fish has skyrocketed in recent years, largely because of the rapid growth in Asian freshwater aquaculture and marine net pen farming of salmon (Delgado et al., 2003). Flesh foods represent over 25% of every supermarket dollar spent on food purchases (Regenstein and Regenstein, 1991). Fish is an important component in the Malaysian diet with per capita consumption at 55 kg, the highest among the ASEAN countries (Pawiro, 2008).

Assessment of consumers' acceptance of freshwater fish usually comprises of two main characteristics which are the texture of the flesh, and its sensory characteristic (Chamber IV and Robel, 1993). Consumption patterns of freshwater fish in Malaysia are not well documented, and it seems to be strongly related to ethnic preference and region. The Chinese population seems to have a higher preference for freshwater fish compared to the other ethnic groups. Regional preferences also seem to exist, but no document is available to verify this observation. Tilapia *(Oreochromis nilotica)*, a freshwater fish species found in abundance in tropical freshwaters is popular in Chinese and Malay cuisines. It contributed about 36% of total freshwater production in the country during the 2000s. Tilapia has a unique sensory characteristic which is different from marine fish. The flesh is more whitish, has a less sour note and salty, which makes it a better choice than marine fish. However, the consumption of tilapia is relatively poor due to the strong muddy odor and flavor associated with it. Other freshwater fish species that are popular with the local population are catfish, pangasius (*patin,* a catfish family) and carp. However, detailed information in this area is still lacking.

Freshwater Fish as Raw Material for the Food Processing Industry

Freshwater Fish: An Alternative Source of Protein

Fish protein can be presented in several forms such as concentrates, isolates or surimi, a wet and frozen form of the protein. The technology for the production of fish protein concentrate as an isolate is fairly established. However, its application in the food processing industry is still limited.

Mince Meat and Surimi Production

Allaskan Pollack (*Theragra chalcagramma*) is the traditional raw material for surimi production. However, due to its decreasing catch, alternative species have been sought and utilized. Active research in this area is being carried out in USA, Japan, Thailand and some European countries such as Spain. Decreasing catch quotas led to a 16 % increase on prices during the first half of the year and further increase is likely in the second half (Anonymous, 2008).

In the European and United States, surimi based products are classified as secondary finfish products and they are produced using mince fish meat alone or in combination with surimi as the raw material (Jamilah, 2004). Commercially, in the Asean countries, threadfin bream (*Nemipterus* sp), bigeye snapper (*Priacanthus* sp.), jewfish (*Sciaena* sp.) and lizard fish (*Synodus* sp) have been used to produce varying grades of surimi (SEAFDEC, 1996). Research reports on surimi produced from other fish species such as Pacific Whiting (*Merluccius productus*), menhaden (*Brevoortia tyrannus*), sardines (*Sardinops* sp), capelin (*Merlotus villosus*), and herring (*Clupea harengus*), to name a few, have been reported (Jamilah, 2004). Surimi produced from eel has been recently marketed in Malaysia. Surimi-based products are gaining more prominence worldwide, because of the emergence of Japanese restaurants and culinary traditions in North America, Europe and elsewhere (FAO,1997). Trial runs in the Food Processing laboratory indicated that tilapia mince meat possesses good gel forming strength and is suitable for incorporation into mince fish products. Below is the picture (Figure 8) of washed tilapia mince meat. The present market price in Malaysia for a frozen surimi block of grade AA varies from RM 150 to RM200 for a 20 kg block.

Figure 8 Washed red tilapia mince meat

Surimi, is of Japanese origin and therefore the technology also originated from Japan. The present technological know-how was pioneered by researches from Hokkaido University, Japan. The original definition of surimi is ground fish meat paste formed during the manufacturing process of the traditional Japanese surimi-based product, ‘kamaboko’. The present definition is, however, slightly different from the original one and surimi is now defined as a wet concentrate of the proteins of fish muscle, mechanically deboned, washed and stabilized. Surimi is an intermediate product used in the preparation of a variety of ready-to-eat seafoods such as Kamaboko, fish sausage, crab legs, imitation shrimp products and fish balls.

‘Surimi’ and ‘surimi-based’ products were first introduced into the Western world in the 1980’s. Growth of interest infor surimi-based products in the West is due to the following factors:

- conversion of underutilized species as raw material
- long shelf-life of frozen surimi
- development of variety of surimi-based products- e.g. meat analogs
- presence of technology for mass production
- Influx of Asian immigrants
- health consciousness of the general public

In 1989, in Canada alone, there were 6 shore-based plants and 19 factory ships dealing with surimi. In the same year, it was also estimated that 20 countries around the world were doing research on surimi. In U.S. several seafood stations actively carried out research to improve the technology for the local resource. All the research reported were on fatty marine species.

Food Ingredients

Food ingredients from fish can be extracted from the fish muscle as well as from the discards of fish processing such as from the filleting and canning operations. With the global push for value adding activities in the food industries and the zero waste concept, recovery of ingredients from fish processing discards has become on of the mainstream focus in the present scenario.

Processing waste from fisheries account for as much as 70-85% of the total weight of catch and these have been generally dumped in-land or hauled into the ocean (Shahidi, 1994). The skin and bone with high collagen content can be processed into gelatin, thus contributing to solving the problem of waste disposal and also in creating a value- added product. The red tilapia skins were found to contain 71.39±0.34 % of moisture, 25.23±0.48 % of protein and 0.21±0.02 % of ash content (Lau, 2004).

The traditional commercial source of gelatin is from mammals, especially bovine and pork. Recent outbreaks of Bovine spongiform encephalopathy (BSE) and increase in demand for *kosher* and *halal* foods have created a demand for fish gelatin for food applications (Muyonga et al., 2004).

Collagen

Collagen is one of the most important structural proteins of the animal body and comprises about 30% of total animal protein. At present, twenty-seven variants of collagen have been identified (Schrieber and Gareis, 2007). The collagen is designated a type when it is shown to arise from a separate structural gene and has a separate biological function (Piez, 1982).

Collagen has been used for food and also for its therapeutic properties. It is incorporated in diet formulae and beverages and of late, it has also been incorporated into lipstick formulations.

Gelatin

The interest in collagen hydrolysis is directed mainly towards the production of gelatin (Petersen, 1981) which is a traditional, functional protein of high value because of its ability to form transparent gels. Gelatin is a polypeptide obtained from collagen after several degradation steps (Fernandez-Diaz et al., 2001). It is a water soluble, hydrophilic protein produced by controlled hydrolysis of water-insoluble collagen substance of skins and bones (Shahidi, 1994). Active research to identify alternative collagen and gelatin sources from seafood, both marine and freshwater, was triggered mainly by the BSE outbreak and the religious issues of the Jews, Muslim and the Hindus. Gelatin is incorporated in food manufacturing as an ingredient to enhance the textural properties of the foods, such as their elasticity, consistency and stability. Among the foods that may contain gelatin are ice-cream, gum drops and puddings. They are also used as clarifying agents in beverage and beer processing. Pharmaceutical grade gelatins are used as capsules and can also be incorporated.

Generally, gelatins are subdivided into Type A (acid pre-treatment) and alkaline pre-treatment. The pH for Type A gelatin ranges between 3.8 to 6.0 and from 5.0 to 7.5 for Type B gelatin (Ockerman and Hansen, 1988). Commercially, pH values of gelatin are between pH 5 and 6 to inhibit bacterial growth and prevent further degradation. Gelatins are evaluated for their gel strength (bloom strength), color, odor and freeze thaw charactrisitics. Grossman and Bergman (1992) and Gudmundsson and Hafsteinsson (1997) reported that pH of gelatin obtained from tilapia skin and cod skin was 3.77 and 2.7-3.9 respectively. The pH of gelatin from red tilapia skin was 3.91 and black tilapia skin was 3.05 (Jamilah & Harvinder, 2002).

Gelatin extraction from red tilapia (*Oreochromis nilotica*) skin under different extraction conditions have been carried out (Lee, 2004**).** It was reported that all the gelatins produced were light in color, powdery and had a slight fishy odor. They are by normal standards acceptable for food application. The yield was in the range of 4.29 to 16.27 %. The peptide profile through SDS-PAGE analysis showed molecular weight of between ~28 kDa and ~95 kDa.

The characteristics of the produced gelatin were also compared to the one commercially available. Differences in characteristics exist and this is not surprising based on the amino acid profiles of the tilapia gelatin extracted where Tilapia gelatin had slightly lower melting points (Harvind, 2001).

Bioactive peptides

Bioactive peptides have been lately recognized as having functional properties that are beneficial to human health. Their functional properties such as anticoagulant, anti-ageing and anti-platelets which reduce the risk associated with cardiovascular diseases are being actively studied. Sources of bioactive peptides are very diverse with fish protein hydrolysates being among the reported sources. These hydrolysates are enzymatically produced from fish muscle and a few reports were found on hydrolysates produced from collagen and gelatin. Rajapakse et al. (2005) reported that a novel anticoagulant had been purified from the marine fish, yellowfin sole (*Limanda aspera*).

PRODUCT INNOVATION FOR FRESHWATER FISH UTILIZATION

Product innovations for utilization of freshwater fish are unlimited. The marketability of the product is highly dependent on promotion and familiarity of the products. Processing pre-treatments, procedures and formulations can overcome the intrinsic unfavorable muddy odor, flavor and aftertaste associated with freshwater fish, as discussed earlier. R & D has to be carried out since although storage stability may be predicted from those of the marine products, however, the changes and rectification steps may not be similar. This is in part due to the physico-chemical properties of the freshwater fish which are not exactly the same as that of marine fish. Examples are the flavor profile and the textural properties of the fish flesh.

Shelf Life of Freshwater Fish-based Products

Fish-based products are very varied. They could simply be a product of simple processing or minimal processing such as frozen whole fish, frozen fillets, frozen battered and breaded fillets and frozen shrimps. There are products that require more intensive processing such as in the processing of fish balls, nuggets and fish cakes. There is also another category of fish-based products that goes through fermentation or hydrolysis steps such as the hydrolysates (fish sauces), shrimp paste (*belacan*) and *pekasam*. Fish can also be canned and smoked where the basic principles appropriate to the preservation techniques are applicable.

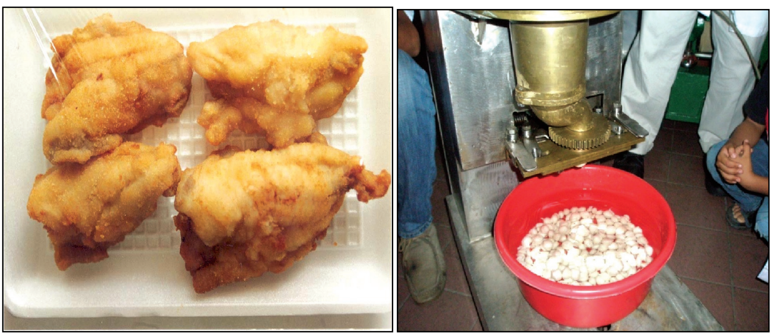
Dried and High Lipid Products

Flosses (*serunding*) are dried high lipid products. They are not known in the Western market. Beef, chicken, marine fish and shrimp floss are common commercial products in Malaysia. These products are prone to rancidity and have a tendency to develop rancid or off-odor and flavor. Tilapia floss (*Serunding ikan tilapia*) has been developed and studied (Jamilah, and Tan, 2000). Storage stability was shortened by the development of rancid odour and flavour, which was due to lipid oxidation. However, the intensity of the various chemical changes and the sensory scores were not similar when compared to the fish floss developed from the marine fish.

Breaded and fried products are also high lipid products due to the oil uptake during the frying process. Frying enhances the flavour and thus increases the acceptability of the product but at the same time predisposes the product to lipid oxidation and other associated chemical reactions. Fabricated tilapia chips were found to exhibit similar shelf life as the traditional marine fish chips (Azelina et al., 2001). The tilapia chips were different from the traditional fish crackers (*keropok*) since they were not formulated and fried but baked as in the processing of fabricated potato chips.

Frozen Products (Surimi-based and Breaded Products)

Commercially breaded products are usually pre-fried and frozen at – 20° C. Due to the frozen storage, product rejection is usually due to textural changes since rancidity development comes in later. Breaded and frozen catfish fillets (Figure 9) were found to have a shelf life of slightly over two months which is slightly shorter than the four months storage period normally recommended for frozen products. This is not completely surprising since catfish is a fatty fish and the lipids are relatively highly unsaturated (Jamilah, 2004).



(a) (b)

Figure 9 Breaded catfish fillets (a) and tilapia fish balls (b)

Temperate fish such as cod, haddock and salmon are among the well-known commercially frozen species. However, with the depletion of these natural resources, the expansion of aquaculture, and the increase in the acceptability of freshwater fish, frozen freshwater fish such as tilapia, eel and catfish are entering the cold-chain (Jamilah, 2004). *Dori*, sold in the frozen fillet form is one of the new freshwater fishes available in the Malaysian market.

It is from the *patin* (*Pangasius* sp) species and is brought in from Vietnam and Thailand.

Mass manufacturing of local delicacies are often overlooked. Challenges in technology is tremendous since very few similar Western foods, which are highly commercialized, share the same characteristics. Often, modifications of the ingredients, the preparation stage and the handling have to be incorporated for mass production. One good example is the *begedel*. The modifications which had to be carried out in order to stabilize the product for longer storage periods at frozen temperature, requires one to investigate certain characteristics such as the acceptability, the freezing behavior and the overall change in the physic-chemical properties of the product. Below (Figure 10) is the cross-section of a frozen tilapia *begedel* (Jamilah et al., 2005).

Reheating by deep-frying — Reheating by microwave

Figure 10 The cross-section of frozen tilapia meat *begedel*

Hydrolysates

Hydrolysates go by different names around the world. In some literature, they are called fish sauces. The hydrolysates have unique characteristic related to its salty flavor and fishy smell.

It is commonly used as seasoning in cooking or as a dip in the oriental food menu. They are known in China, Japan and Southeast Asia. They are both clarified and non-clarified. In Malaysia, the hydrolysate is not clarified and is commonly known as *budu*. In other parts of the world, such as in Thailand, Japan and China, they are marketed in the clarified form. The most popular raw material for hydrolysate in Malaysia is anchovy. However, in other parts of the world the hydrolysates are produced from different marine species such as squid.

Hydrolysates are the product of enzymatic hydrolysis. In Malaysia, the production of hydrolysates is very much dependent on the natural enzyme and the hydrolysis can take up to 4 to 5 months (Figure 11). The new technology which has been put in place in commercial production is the use of commercial enzymes which can complete the hydrolysis within a few hours. Precise characteristics such as bitterness and the *umami* note can also be controlled.

Figure 11 Showing the sequence of *budu* processing (a) the salting process, (b) the fermentation process, (c) the cooking process and (d) the final product

CONCLUSION

Based on the information collected and discussed above, it could be concluded that freshwater fish can be an alternative food and raw material for the food processing industry either as a competitor or complementary to the utilization of marine fish.

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BIOGRAPHY

Jamilah Bakar was born in Alor Star, Kedah. She spent her early schooling days in Selangor and Pahang. After completing her Form Five education, she left for the United States in 1974 to pursue her first degree in biology under the Public Service Department Scholarship. She obtained her BS (Biology) from University of Oregon, Eugene, Oregon in 1978. She later continued her MS at Louisiana State University, Baton Rouge, Louisiana, USA, and obtained her MS (Food Science) with a minor in microbiology in 1980.

Although Jamilah had secured a place to continue her PhD, due to lack of financial resources, she returned to Malaysia and joined Universiti Pertanian Malaysia, Serdang, Selangor in January, 1981. She was awarded a research grant by the ASIAN Fishery Society for best written research proposal in 1990, and she enrolled as a PhD candidate in the same year at the Faculty of Food Science and Biotechnology and obtained her PhD in 1993. She was promoted to the post of Associate Professor in 1997 and Professor in 2003.

During her tenure at the Faculty, she had several research attachments. In 1981, she went to Bombay, India and obtained a certificate in Packaging under the joint program of the Indian Institute of Packaging and MIT, USA. She was funded by JICA to be trained in fish processing and preservation at University of Kagoshima, Kagoshima, Japan in 1988. In early 1990, she went to University of British Columbia, British Vancouver, Canada, for research attachment on protein technology. She was trained as a trainer for HACCP in seafood processing under the joint program of USDA Seafood Alliance and FAO in 1994. In 1997, she participated in a program for trainers in auditing and verification of seafood processing premises organized by FAO and The Malaysian Department of Fisheries.

Her research interest covers the area of Food Technology (handling, processing and preservation of plant and animal-based food commodities). Her specialization is in Seafood Technology (handling, processing, preservation and renewable resources from aquatic commodities).

Administratively, she has served as coordinator and organizer of various projects undertaken by the Faculty. She was the coordinator and one of the lecturers involved in the Advance Food Processing Module (Module 3) under the ASIAN-European Link Program for MS in Food Technology. She also served as the Head of Department of Food Technology and is presently the Deputy Dean (Graduate studies, research and Innovation) at the Faculty of food Science and Technology.

Jamilah's interest and ambition to improve the practices in the local food processing and related industries inspired her to do various extension and consultation assignments. She is active in extension and consultation work involving SMIs in food processing. She has also carried out consultation works for private firms and government organizations. She also sits on the technical committees in SIRIM and is a member of the Codex Alimentarius Malaysian Chapter for Fishery Products.

LIST OF INAUGURAL LECTURES

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   The Challenge to Communication Research in Extension
   22 July 1989

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   Indigenous Materials and Technology for Low Cost Housing
   30 August 1990

3. Prof. Dr. Abdul Rahman Abdul Razak
   Plant Parasitic Nematodes, Lesser Known Pests of Agricultural Crops
   30 January 1993

4. Prof. Dr. Mohamed Suleiman
   Numerical Solution of Ordinary Differential Equations: A Historical Perspective
   11 December 1993

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   Changing Roles of Agricultural Economics
   5 March 1994

6. Prof. Dr. Mohd. Ismail Ahmad
   Marketing Management: Prospects and Challenges for Agriculture
   6 April 1994

7. Prof. Dr. Mohamed Mahyuddin Mohd. Dahan
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   20 April 1994

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   Plant Taxonomy, Biodiversity and Conservation
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