# An Annotated Bibliography on the current status and product development of *Tilapia* in Fiji, Samoa and Tonga

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FACULTY OF SCIENCE TECHNOLOGY AND ENVIRONMENT
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*G. Robin South*

Faculty of Business & Economics,
The University of the South Pacific
Alafua Campus, Apia, Samoa

*Cherie Morris & Shirleen Bala*

Institute of Marine Resources
The University of the South Pacific
Suva, Fiji

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# Preface

*Tilapia* is one of the most cultured freshwater fish in the world, and is farmed in more than 100 countries (Norman-Lopez & Bjorndal, 2009). A hardy and prolific, fast-growing tropical fish, it requires low input during grow-out periods and can be farmed successfully on any level, from extensive to intensive culture in ponds, tanks or raceways (Fitzsimmons, 2006). It is disease resistant, tolerant of poor water quality, can eat a wide range of food types and be cultured in fresh or brackish water. Chemicals and antibiotics are not necessary for commercial farming (Fitzsimmons, 2008).

Introduced into the Pacific Islands region in the 1950s, tilapia became a commodity for culture due to its low-cost and success in other regions. For Fiji and Samoa, tilapia was for human consumption and as potential pig feed (Costa- Pierce, 1998), although in Tonga it became an unsuccessful attempt to control mosquitoes. Fiji and Papua New Guinea both have policies of government support for tilapia farming in rural areas. Household-scale tilapia farming is common in the Pacific but medium-scale enterprises are now on the increase (Teri & Pickering, 2009).

Efforts in value adding of tilapia have been minimal in the Pacific (www.spc.int). Tilapia is mostly sold live or fresh in bundles but interestingly in Papua New Guinea, cooked tilapia (fried) is sold on the roadsides (Ponia & Mobiha, 2002). Simple village level post-harvest processing, such as smoking may exist in some countries (www.spc.int) but proper documentation is absent.

This annotated bibliography was developed as part of the Scoping Study for PARDI 2010/002 prepared by South, G.R., *et al*., 2011. *Scoping study for Tilapia (Oreochromis sp.)*. Suva: Institute of Marine Resources, School of Marine Studies, FSTE, USP. References are specific to the Pacific or are directly related to the project. Most of the references are annotated.

**References**

Costa-Pierce, B.A. (1998). Market-driven tilapia aquaculture development: results from a domestic and export marketing and industry study for Fiji. *Aquaculture '98 Book of Abstracts*, pp.122.

Fitzsimmons, K. (2008). *Tilapia product quality and new product forms for international markets.* Proceedings of the 8th International Symposium on Tilapia in Aquaculture, Cairo, Egypt, October 12-14.

Fitzsimmons, K. (2006). *Prospects and potential for global production*, In: Lim, C. & Webster, C.D. (eds.), Tilapia biology, culture and nutrition. New York: Haworth Press, pp.51-72.

Norman-López, A., & Bjørndal, T. (2009). Is tilapia the same product worldwide or are markets segmented? *Aquaculture Economics Management*, *13*(2): 138-154.

Ponia, B. & Mobiha, A. (2002). Aquaculture in Papua New Guinea. *SPC Fisheries Newsletter 101*: 18-25.

Teri, J. & Pickering, T. (2009). *Productivity and constraints in tilapia fish and freshwater prawn aquaculture in Fiji.* ACIAR Mini-Project MS0507.

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## *Biology*

**Macaranas, J. M., Mather, P. B., Lal, S. N., Vereivalu, T., Lagibalavu, M., & Capra, M. F. (1997). Genotype and environment: a comparative evaluation of four tilapia stocks in Fiji. *Aquaculture*, *150*(1-2): 11-24.**

The reproductive, survival and growth performance of four tilapia strains in Fiji, namely Oreochromis mossambicus (M), `Israel' Oreochromis niloticus (NI), `Chitralada' O. niloticus (NC) and Red tilapia hybrid (R) were evaluated in two culture environments currently used in Fiji (integrated and non-integrated farming) for three generations. Results showed significant differences among strains in all traits. Overall, the M strain had the highest breeding efficiency and average fecundity but the poorest growth rate. The NI strain showed the highest survival and a good growth rate but low breeding efficiency and fecundity. Although the R strain showed a good growth rate in favorable environments, it was prone to stress under less optimal conditions and had a relatively low survival rate and only average fecundity. The NC strain showed the best growth rate and feed conversion efficiency, relatively good breeding efficiency but average fecundity and survival. Based on a weighted performance across all traits, the NC strain was identified as the best performing strain in Fijian conditions. Significant genotype-environment interactions estimated during harvest were due to a strong rank interaction in the R strain and also magnitude interactions in the NC and NI strains. Growth performance of the M strain showed the lowest response to quality of culture environment. Future approaches to improving tilapia production in Fiji are discussed.

**McKinna, E. M., Nandlal, S., Mather, P. B., & Hurwood, D. A. (2010). An investigation of the possible causes for the loss of productivity in genetically improved farmed tilapia strain in Fiji: inbreeding versus wild stock introgression. *Aquaculture Research*, *41*(11): 730-742.**

Four microsatellite markers and a mitochondrial DNA (mtDNA) fragment were used to investigate two possible explanations for a reported decline in productivity of genetically improved farmed tilapia (GIFT) in Fiji: (i) a decline in genetic diversity (GD) and (ii) genetic introgression from feral tilapia populations. Genetic diversity was estimated using θ and allelic richness, while Bayesian clustering was used to assign individuals to genetic groups ($K$=2 or 3) to test for introgression. Differentiation among groups was estimated using $F_{ST}$ analysis. Results indicate that genetic diversity had declined compared with a GIFT reference stock from WorldFish Centre, while there was little evidence for introgression from feral tilapia populations. Loss of genetic diversity most probably resulted from practices that have not actively managed genetic resources in the hatchery. While GIFT is considered to be an improved line of Nile tilapia (*Oreochromis niloticus*), mtDNA analysis here revealed haplotypes assigned previously to three discrete *Oreochromis* species (*O. niloticus, Oreochromis mossambicus* and *Oreochromis aureus*) in both the Fijian strain and the WorldFish Centre strain. Possible sources for the three divergent lineages are discussed. Results have implications for the management and future expansion of the tilapia culture industry in Fiji as well as in other Pacific island nations.



**Mjoun, K., Rosentrater, K.A. & Brown, M.L. (2010). *Tilapia: profile and economic importance.* South Dakota, US: South Dakota State University.**

An economic profile of Tilapia showing its world production and trade figures along with the latest US production and consumption figures. A comparison is also made between the nutrient composition of raw tilapia, raw ground beef and raw chicken breast.

http://pubstorage.sdstate.edu/AgBio_Publications/articles/FS963-01.pdf

**Nelson, S., & Eldredge, L.G. (1991). Distribution and status of introduced cichlid fishes of the genera Oreochromis and Tilapia in the islands of the South Pacific and Micronesia. *Asian Fisheries Science*, *4*(1): 11-22.**

Fishes of the genera Tilapia and Oreochromis have become established in a variety of habitats on numerous islands of the South Pacific and Micronesia. Reproductive populations of tilapias can be found in lakes, reservoirs, streams, rivers, mangroves and shallow lagoons. The reasons for the introductions include mosquito control, aquatic weed control, culture, stock enhancement and accidental release. Consequences of the introduction of tilapias have ranged from dramatic improvements of inland fisheries and the significant development of subsistence and commercial aquaculture to detrimental effects both on indigenous species and on traditional fish culture systems.

## *Culture*

**De Silva, S.S., Subasinghe, R.P., Bartley, D.M. & Lowther, A. (2004). *Tilapias as alien aquatics in Asia and the Pacific: a review.* FAO Fisheries Technical Paper 453. Rome, FAO.**

Tilapias are not native to Asia but have been a significant component of inland fisheries and aquaculture in the region for over half a century. They have been introduced into over 90 countries worldwide, with a global distribution second only to common carp. The contribution of tilapias to global aquaculture production has increased over the past three decades with production in 2002 exceeding 1.5 million tonnes with an estimated value of US$1.8 billion. The average annual growth rate in aquaculture and capture fisheries production of tilapias from 1970 to 2002 has been 13.2 percent and 3.5 percent, respectively. In the present context of development, success of a species is determined not only by its contribution to production *per se*, but also by its social, cultural, economic and environmental impacts. Although tilapia has been associated with adverse environmental impacts, detailed analysis of the literature suggested that other factors, such as overfishing, environmental degradation from land-based activities, and changes in hydrological regime have probably been more responsible for adverse impacts. It is clear that numerous factors working together can impact biodiversity. It is also clear that tilapias, as a group of alien species, have made a significant contribution to food production, poverty alleviation and livelihoods support in Asia and the Pacific. In spite of the wide-scale introduction into Asian waters, there is scant explicit evidence to indicate that tilapias have been overly destructive environmentally.

http://www.fao.org/docrep/007/y5728e/y5728e00.htm#Contents

**El-Sayed, A.F.M. (2006). *Tilapia culture*. Cambridge, MA: CABI.**

Written primarily for those engaged in tilapia education, research and production, the book covers current state and future potential of global tilapia production, biology, culture, reproduction, nutrition and reducing environmental impacts. It also covers the history of tilapia culture to the latest production practices being used around the world, from morphology to socio-economics.

**Fitzsimmons, K. (2000). *Future trends of tilapia aquaculture in the Americas,* In Costa-Pierce, B.A. & Rakocy, J.E. (eds.), Tilapia aquaculture in the Americas (Vol. 2). Baton Rouge, Louisiana, United States: The World Aquaculture Society, 252–264pp.**

Tilapia is a relatively new seafood product in the Americas. Aquaculture of tilapia in the Americas began with small scale culture for subsistence farming in the late 1960s and 1970s with large scale production and international trade of tilapia products in the 1980s and 1990s. Rapid increases in production can be attributed to improvements in aquaculture technology and infrastructure in several nations in the Americas that are major producers, and to greater numbers of trained biologists. Increases in consumption of tilapia are the result of more consumer recognition, improved quality, variety of product forms, better marketing, and overall increased demand for fish products. The Mozambique tilapia, *Oreochromis mossambicus*, was the first species widely distributed in the Americas and still accounts for a significant proportion of tilapia production. Other tilapia species, hybrids and strains have since become more popular. In the future, we can expect a decrease in the number of species farmed and an increase in the number of strains or breeds of *O. niloticus* and red hybrid strains available. The volume of tilapia produced in the Americas is likely to double in the next decade. Most of these increases will occur in tropical regions. Temperate regions will see a moderate increase in production that will primarily supply niche markets for live fish and local fresh product. In both the tropics and temperate zones, production will become more intensive with more complete diets, aeration, water reuse, and disease control as important factors. Another trend that is likely to continue is increased processing in the country of origin. Levels of sophistication in production, processing, and packaging have risen considerably in recent years and this trend will continue. Domestic markets outside the US and Canada are absorbing higher value forms of tilapia. This increase in demand for filleted and packaged products has benefited producers outside the US by reducing transportation costs and smoothing out demand swings.

**Fitzsimmons, K. (2006). *Prospects and potential for global production*, In: Lim, C. & Webster, C.D. (eds.), Tilapia biology, culture and nutrition. New York: Haworth Press, pp.51-72.**

The increasing role of farm-raised *Tilapia* sp. in the international seafood trade, global production of farmed *Tilapia* sp., consumption, microenterprise, regional production and markets, industry predictions and outlook for *Tilapia* sp. culture and the increasing markets for *Tilapia* sp. are discussed.



**Fitzsimmons, K., Martinez-Garcia, R. & Gonzalez-Alanis, P. (2011). *Why tilapia is becoming the most important food fish on the planet.* In: Liping, L. & Fitzsimmons, K. (eds.). Better science, better fish, better life: proceedings of the ninth international symposium on tilapia in aquaculture. Corvallis, Oregon: AquaFish Collaborative Research Support Program.**

Tilapia has become the shining star of aquaculture with farms starting and expanding across the globe while consumption races ahead of even the most ambitious farm building plans. The year 2010 saw farmed tilapia exceed 3.2 million metric tons per annum, surging further ahead of the salmon and catfish industries. We are also seeing an explosion of product forms in grocery stores that are only matched, by the variety of preparations we see in the restaurant trade. The global adoption of tilapia as a substitute for all kinds of wild-caught fish has driven demand higher every year, even through the global recession of recent years. The description of tilapia as an “aquatic chicken” becomes more accurate every day. It’s wide acceptance across all cultural, religious, and economic groups is similar to chicken. A variety of breeds and strains have been developed and by most measures, tilapia is now the most highly domesticated of farmed fishes. Unique amongst the major farmed fishes, tilapia maintains a key role in rural aquaculture improving the welfare of the poorest farmers while at the same time, it is reared in the most high tech production systems and is sold into international markets for up-scale markets. Tilapia is still the darling of the environmental community and the industry continues to polish its “green” credentials. Three or four closely related species of tilapias readily hybridize in captivity and produce fecund F1 progeny. This has provided a huge genetic base for the geneticists to perform basic selective breeding. The domestication of tilapias has been a great driver of productivity during the 1990’s and 2000’s. There is also a concerted effort to describe the tilapia genome. When these genetic maps are distributed we can expect a second wave of genetic research that should further improve productivity. All of this will have been accomplished without the need of transgenics or genetically modified organisms. The basic biology of the fish along with the skill of traditional breeders has provided all of the progress to this point and much more in the near future. Tilapia continues its march towards eventually overtaking carp as the most important farmed fish crop. With a much wider distribution of production and consumption and a huge base of value added product forms, it is almost certain that tilapia production will someday eclipse that of carp. As tilapia production and consumption grows globally, it is likely to become the foundation product for all farmed fishes, just as chicken is the base for the poultry industry. So someday soon instead of referring to tilapia as the aquatic chicken we may be referring to chicken as the “terrestrial tilapia”.

http://ag.arizona.edu/azaqua/ista/ISTA9/PDF%27s/ISTA9%20EntireProceedingsText.pdf

**Globefish. (2010). *Tilapia Market Report*. Rome: FAO.**

*Globefish* is the unit in the FAO Fisheries Department responsible for information on international fish trade. It produces a number of publications including fish price reports (European Fish Price Report), market studies (GLOBEFISH Research Programme) and trend analysis (GLOBEFISH Highlights). Globefish’ *Tilapia Market Report* provides the latest export and import trends in international and domestic markets of key tilapia production countries.

http://www.globefish.org/tilapia.html

**Josupeit, H. (2005). World market of Tilapia. *GLOBEFISH Research Programme, Vol. 79.* Rome: FAO.**

Tilapia is one of the most popular fish cultured in the world and production is increasing. Wild tilapia production is also important. As with carp, tilapia is one of the most widespread farmed fish species in the world, produced in approximately 75 countries. The tilapia market is expected to increase markedly, and this study provides examples of investment in tilapia in numerous countries. The price of tilapia is expected to fall on the wave of increased production. In the United States of America, the price of fresh tilapia fillets is currently US$3.50/lb (US$7.70/kg), already 15 percent below the previous year's price. The tilapia price compares with US$2.85/lb (US$6.27/kg) for catfish. Tilapia is thus on its way to becoming a major supplier of protein in both the developed and the developing world. Fortunately, there is no risk that, by increasing tilapia imports into the United States of America or Europe, affordable protein will be taken from the poor of the world: the tilapia sold cheaply on local markets would not be saleable in the West. Indeed, such tilapia comes from intensive farms, from small water areas or rice farms and is generally very small and not very homogenous. In contrast, the product destined for export is of consistent quality, size, colour and texture. It is to be hoped that the increase in production and exports of tilapia will also increase employment in producing countries.

http://www.globefish.org/upl/Publications/GRP%2079%20Tilapia%20Markets%20MAILING.pdf

**Lal, S.N. (1996). *Report on tilapia demonstration farm in Western Samoa.* Technical Report, Western Samoa Fisheries Department. Suva: FAO/ South Pacific Aquaculture Development Project. 10p.**

Report outlining work done in conducting surveys on the sites proposed for tilapia farming by the Fisheries Division and selecting the best site for construction of a demonstration tilapia farm. Due to past experience of Salani ponds, the Division decided to site the demonstration pond at Channel College though the other sites (Lotego and Lotofaga) were better sites but were too far from Fisheries Division office for management and follow-up visits. Designed and supervised construction for an appropriate layout of ponds, two for grow-out and two for broodstock and the consultant also organized a workshop for the Fisheries Division staff and potential fish farmers on tilapia farming techniques, pond construction, site selection, water connections/ requirements and management. Survey for feeds were carried out and tilapia broodstock conditions were assessed.

**Lal, S.N. & Foscarini, R. (1990). *Introduction of tilapia species and constraints to tilapia farming in Fiji.* FAO/ South Pacific Aquaculture Development Project Report AC295/E. 23p.**

Tilapia species have been periodically introduced in Fiji since 1949. The main reason for the introduction was to provide animal protein feed to piggeries. In later years, the idea of utilizing Tilapia species for human consumption took root and for the last 10 years *Oreochromis niloticus* has been the species of choice for aquaculture purposes. Since 1983 fish ponds were constructed in the interior areas of Viti Levu and Vanua Levu for the purpose of providing supplemental animal protein to the protein-deficient inland rural communities. Uncontrolled introduction, accidental or intentional release of Tilapia species in rivers and streams, has led to genetic contamination through free cross-breeding of wild dwelling populations during flooding with the broodstock kept in the hatchery for breeding purposes. Probably due to genetic contamination, the performance of the broodstock deteriorated resulting in poor quality fry. Hatchery-reared fry, once stocked for grow-out in village ponds, reproduced early and the growth rate was low. Appropriate feed composition and preparation represent a constraint for improving yields. In addition, feed components are irregularly available and their cost high due to competition with other animal husbandry practices. Additional constraints to fish farming development are identified in the lack of trained manpower, land tenure and financing initial costs in the country.

http://www.fao.org/docrep/field/003/AC295E/AC295E00.htm

**Lal, S.N. & Pickering, T. (2004). *Tilapia fish farming in Pacific Island countries. Volume 1. Tilapia hatchery operation.* Noumea, New Caledonia: Secretariat of the Pacific Community.**

Developed from USP-SPC led training workshops in Fiji, the book is intended for use by fisheries extension officers, staff of rural community development projects, school teachers, or other people with some basic knowledge of biology to help them impart fish-culture practices to people engaged in tilapia fingerling production. It can also be used by more advanced fish farmers who want to further improve their skills and their self-reliance by producing their own tilapia fry and fingerlings. This book is written specifically for Pacific Island countries and is based upon practical experience of what works in its varied environmental and cultural circumstances.

http://www.spc.int/DigitalLibrary/Doc/FAME/Manuals/Nandlal_04_Tilapia1.pdf

**Lal, S.N. & Pickering, T. (2004). *Tilapia fish farming in Pacific Island countries. Volume 2. Tilapia grow-out in ponds.* Noumea, New Caledonia: Secretariat of the Pacific Community.**

This second volume is intended for fish farmers at subsistence or small-scale commercial level and can be used as a textbook for training by the Fisheries Department officers, staff of rural community development projects, school teachers, or other people responsible for imparting good fish-culture practices to people engaged in tilapia fish farming in Pacific Island countries. This volume assumes less biological knowledge, has more emphasis on practical techniques for raising tilapia in ponds hence, making it more suitable for people who are new to fish farming or who only want to be involved in the grow-out of tilapia.

http://www.spc.int/DigitalLibrary/Doc/FAME/Manuals/Nandlal_04_Tilapia2.pdf

**Lim, C.E. & Webster, C.D. (eds.). (2006). *Tilapia: biology, culture and nutrition*. NY: Food Products Press.**

This book gives a comprehensive, up-to-date review of the scientific literature of tilapia aquaculture. Material presented ranges from its biology to culture in the full range of fresh- and saltwater culture systems, tilapia hormones, nutrition, diseases and marketing. Each chapter details the history of the topic, from the early efforts to current industry techniques used in different parts of the world.

**Liping, L. & Fitzsimmons, K. (eds.). (2011). *Better science, better fish, better life: proceedings of the ninth international symposium on tilapia in aquaculture*. Corvallis, Oregon: AquaFish Collaborative Research Support Program.**

This reports the ninth highly successful series of symposia that have brought together tilapia biologists who review the latest discoveries in tilapia nutrition, physiology, reproductive biology, genetics, ecology, improvements in production systems, and other fields related to tilapia and their use in aquaculture. The symposium had a special emphasis on best management practices, quality control, new product forms, international trade, and opening new markets for farmed tilapia products. It also included a trade/exhibit show, which provided a forum for industry suppliers, seafood marketers, and the aquaculture press to meet directly with researchers and producers.

http://ag.arizona.edu/azaqua/ista/ISTA9/PDF%27s/ISTA9%20EntireProceedingsText.pdf

**Lochmann, R. & Perschbacher, P. (n.d). *Nutritional contribution of natural and supplemental foods for Nile Tilapia: stable carbon isotope analysis (effect of preservation method on stable carbon isotope ratios of plankton and tilapia).* Eighth Work Plan, Kenya Research 3A (KR3A), University of Arkansas at Pine Bluff: Aquaculture/Fisheries Center.**

In the present study, stable carbon isotopic analysis will be used to obtain quantitative estimates of the contribution of natural and supplemental feeds to the nutrition of tilapia in ponds in Sagana, Kenya. This can be accomplished by comparing the carbon isotopic “signatures” of tilapia with their known and probable food sources. The assumption underlying the technique is that the fish isotopic profiles will resemble that of the food(s) they assimilate most. The results may indicate how feeding/fertilization practices can be adjusted to minimize feed costs while maximizing fish production.

http://pdacrsp.oregonstate.edu/pubs/technical/15tch/4.c.3.pdf

**Muir, J.F. & Roberts, R.J. (eds). (1988). *Recent advances in aquaculture. Vol. 3* London: Croom Helm.**

The aquaculture industry continues to experience rapid growth throughout the world. This is the third part of a series of books that provide up-to-date and timely reviews of current developments in the industry. The breadth of material in Volume 3 is considerable, ranging from fish diseases and reproduction to the effects of light and acid rain on fish growth and health.

**Norman-López, A., & Bjørndal, T. (2009). Is tilapia the same product worldwide or are markets segmented? *Aquaculture Economics Management, 13*(2): 138-154.**

Tilapia is one of the fastest growing aquaculture species in the world. It is produced and consumed in all continents and in more countries than most other species, making the market more heterogeneous than for other successful aquaculture species such as salmon and shrimp. This paper investigates the degree of market integration between tilapia from the three largest production regions, Asia, Africa and South and Central America. We consider differences in the production methods, transport costs and qualities of these regions and determine whether tilapia products from different producers can essentially be considered the same product. This is important if the rapid worldwide development of farmed tilapia and its future development prospects are to be better understood. Tilapia is one of the fastest growing aquaculture species in the world. It is produced and consumed in all continents and in more countries than most other species, making the market more heterogeneous than for other successful aquaculture species such as salmon and shrimp. This paper investigates the degree of market integration between tilapia from the three largest production regions, Asia, Africa and South and Central America. We consider differences in the production methods, transport costs and qualities of these regions and determine whether tilapia products from different producers can essentially be considered the same product. This is important if the rapid worldwide development of farmed tilapia and its future development prospects are to be better understood.



**Pickering T. 2009. Tilapia fish farming in the Pacific: a responsible way forward. *SPC Fisheries Newsletter Information Bulletin 130*: 24-26**

In many islands of the Pacific, the environmental costs from past introductions of tilapia have already been paid. How can people in these places now responsibly obtain the expected social benefits? This article looks at discussions at the SPC Meeting titled ‘Future directions for tilapia in the Pacific.’ It is obvious that the demand for fresh fish in the region will increasingly drive new initiatives to farm tilapia. Already the region is witnessing an expansion from household-scale fish farming projects to economically viable medium-scale enterprises based on aquaculture of this versatile fish. If this industry is to expand in a responsible and environmentally sustainable way, participants noted that the success of new entrants to tilapia farming will depend on working with suitable domesticated varieties. This means having the capacity to manage aquatic-species quarantine protocols at the national level. It also means carrying out an import risk assessment for the proposed new variety, to ensure that no characteristics (such as higher salt tolerance) are added to the local feral tilapia gene pool that may increase invasive properties any further. Zoning approaches to aquaculture planning can be developed to protect areas of high conservation value from the introduction of tilapia. The need for, and viability of, a tilapia farming industry should be assessed country by country before any decision is made to go ahead with it. SPC plans to work with its member countries to further develop these and other ideas in support of sustainable and profitable tilapia farming in the Pacific Islands region.

http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/130/FishNews130_24_Pickering.pdf

**Ponia B. (2010). *A review of aquaculture in the Pacific Islands 1998-2007: tracking a decade of progress through official and provisional statistics.* Noumea, New Caledonia: Secretariat of the Pacific Community.**

A provisional desktop review of aquaculture in the Pacific was carried out by the SPC on behalf of its 22 Pacific Island member countries and territories in order to bridge an information gap. Government statistics tend to be limited to export data and Fisheries departments occasionally publish production in their annual reports or in reports to the FAO, but statistics are often recycled. If values for known production were not provided, an SPC ‘best estimate’ was made based on expert opinion so the data should be viewed as provisional until the estimates can be replaced with official statistics. With regards to seaweeds and tilapia, the production by commodity summary for Algal culture consists mostly of kappaphycus seaweed (*Kappaphycus alvarezii*). The 2007 harvest was a low point for the region. In the past, mozuku seaweed (*Cladosiphon* sp.) has been intermittently cultivated in Tonga. For tilapia, Finfish production in 2007 was 464 t worth USD 2 million. This was mostly composed of Nile tilapia (*Oreochromis niloticus*) worth USD 1.3 million and milkfish (*Chanos chanos*) worth USD 0.3 million. Mozambique tilapia (*Oreochromis mossambicus*) is also harvested from ponds, but no statistics on volume are

available. The most finfish the region has harvested in any year was 612 t in 2000, mainly consisting of Nile tilapia.

http://www.spc.int/DigitalLibrary/Doc/FAME/Reports/Ponia_10_AquacultureReview.pdf

**Ponia, B. & Mobiha, A. (2002). Aquaculture in Papua New Guinea. *SPC Fisheries Newsletter 101*: 18-25.**

Papua New Guinea (PNG) has a long history of aquaculture development. The early 1990 saw renewed interest in aquaculture and this article summarizes some of the aquaculture developments a decade later. With regards to tilapia, there are two species: *Tilapia rendalli* and *T. mossambicus* commonly found in PNG. *T. mossambicus* escaped from ponds in the Highlands and became well established in PNG's river systems, particularly the Sepik River. Tilapia is now one of the most important food sources in this area. Because of its high fecundity, however, this species of tilapia is not good for aquaculture. There is considerable interest in a new genetic strain of the Nile tilapia (*Oreochromis niloticus*) bred during a project known as "Genetic Improvement of Farmed Tilapias" or the GIFT project. GIFT tilapia grows up to 60% faster than the most commonly farmed species of tilapia.

http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/FishNews/101/FishNews101_18_Ponia.pdf

**Popma, T.J. & Lovshin, L.L. (1995). *Worldwide prospects for commercial production of Tilapia.* Auburn University, Alabama: International Center for Aquaculture and Aquatic Environments, Department of Fisheries and Allied Aquacultures**

Tilapias are endemic to Africa, but interest in their aquacultural potential led to nearly worldwide distribution within the past fifty years. Initial enthusiasm was based on characteristics that made tilapia appropriate for subsistence fish farming in developing countries: several species are herbivorous, readily reproduce in small ponds and are highly tolerant of poor water quality. Interest in commercial production of tilapia was initially dampened by a small harvest size resulting from excessive reproduction and stunting. Within the past thirty years, however, commercially viable techniques have been developed to control overcrowding in ponds, thereby permitting growth to more marketable sizes. Total world landing of tilapia is now about 1.2 million MT annually, of which more than half (670,000 MT) is farmed. In the USA, total consumption of tilapia is about 51,000 MT, but less than one-fifth (a little more than 8,000 MT) is produced domestically. The rest is imported from Latin America and the Caribbean (where total production exceeds 200,000 MT annually). Tilapias are rapidly becoming more accepted worldwide by middle-class and upscale producers. Production will continue to expand as the market for farmed tilapia grows. This publication looks at the overall description of the production characteristics of tilapia, with production techniques the focus rather than economic analyses.

**Prasad, R. (2003). Aquaculture potential in Fiji and other Pacific Island Countries. *Micronesica Supplement 7*: 55–67.**

Examples of aquaculture ventures in the Pacific Islands show that reasonable development has occurred. While some earlier and ill planned projects failed, recent initiatives have shown good results. Future prospects look good for pearl oyster, seaweed, marine and freshwater shrimps, and tilapia. A number of pitfalls must be avoided, however, for aquaculture to reach its potential for economic development in the islands.

http://www.uog.edu/up/micronesica/dynamicdata/assetmanager/images/suppl7/55-67prasad.pdf

**Rakocy, J.E., Bailey, D.S., Shultz, R.C. and Thoman, E.S. (2004). *Update on Tilapia and vegetable production in the UVI aquaponic system.* US: University of the Virgin Islands, Agricultural Experiment Station.**

The UVI commercial-scale aquaponic system has produced Nile and red tilapia continuously for 4 years. During that time, two trials have been conducted to evaluate the production of basil and okra. Tilapia were harvested every 6 weeks from one of four 7.8-m3 rearing tanks. Nile and red tilapia were stocked at 77 and 154 fish/m3, respectively. During the last 20 harvests, production of Nile and red tilapia averaged 61.5 and 70.7 kg/m3, respectively. Mean harvest weight was 813.8 g for Nile tilapia and 512.5 g for red tilapia. Nile tilapia attained a higher survival rate (98.3%) and a lower red conversion ratio (1.7) than red tilapia (89.9% and 1.8, respectively). Projected annual production is 4.16 mt for Nile tilapia and 4.78 mt for red tilapia. Batch and staggered production of basil in the aquaponic system was compared to field production of basil using a staggered production technique. Annual projected yield of basil is 25.0, 23.4 and 7.7 kg/m3 for batch, staggered and field production, respectively. Annual projected yield of basil for the aquaponic system is 5.34 mt for batch production and 5.01 mt for staggered production. However, batch production was not sustainable with the current fish output because nutrient deficiencies occurred. The okra trial compared the production from three varieties (Clemson, Annie Oakley and North South) and two planting densities (2.7 and 4.0 plants/m2) in the aquaponic system. One variety (Clemson) was cultivated in a field plot at the low planting density. The highest production (3.04 kg/m2) was attained by the variety 'North South' at the high density. Projected annual production of 'North South' is 13.37 kg/m2 and 2.86 mt per system. Field okra grew slowly and produced only 0.15 kg/m2. The aquaponic system performed well over a sustained period of time. Aquaponic production of basil and okra was dramatically higher than field production.

**Samoa Fisheries Division (2010). *Fisheries Division Annual Report for the fiscal year 2009-2010.* Apia: Ministry of Agriculture and Fisheries.**

The Fisheries Division consists of the following 6 Sections namely Advisory Services, Coastal Fisheries, Oceanic Fisheries, Aquaculture, Compliance, and Fish Market & Administration, which interrelate and collaborate to provide the services and technical support for its stakeholders and the general public. The Aquaculture Section is responsible for farming aquatic organisms (bivalves) in seawater (mariculture) and tilapia in freshwater to alleviate marine fishing pressure. In an effort to lessen fishing pressure on the over-exploited near-shore fishery resources, aquaculture projects such as stocking of natural lakes/ ponds and lagoon areas are implemented. The Fisheries Division is the main supplier of tilapia fingerlings to the local tilapia farmers. Currently the fingerlings are free of charge for initial stocking. Should the industry expand there will be a need for the FD hatchery to expand to meet the demand and set prices to sell fingerlings. A total of 8,034 tilapia fingerlings were distributed to eight new farmers (7 in Upolu and 1 in Savaii) and restocking of 18 existing farms in Upolu. Overall an average size of 9 cm fingerlings was distributed at an estimated weight of 9.5 g, presuming the estimated tilapia produced and distributed at this fiscal year (2010 – 2011) will be 886.97 kg.

**Secretariat of the Pacific Community. (2003). *Profiles of high interest aquaculture commodities for Pacific Islands countries.* Noumea, New Caledonia: Secretariat of the Pacific Community. Secretariat of the Pacific Community. SPC Aquaculture Technical Papers. 73p.**

Profiles of the top 17 aquaculture commodities for Pacific Islands which included seaweed groups Eucheuma, cottoni (*Kappaphycus alvarezii*), lumi wawa, ogonori (*Gracilaria* spp.), lumi cevata (*Hypnea* spp.), tosakanori (*Meristotheca procumbens*), nama, seagrapes (*Caulerpa racemosa*), limu tanga'u, mozuku (*Cladosiphon* sp.) and tilapia. Details provided include attributes for stock enhancement, culture methods, current production status, marketing and the advantages and risks of producing the species in the Pacific.

http://www.spc.int/DigitalLibrary/Doc/FAME/Reports/Anon_05_ComProfiles.pdf

**Shapira, N., Weill, P., Sharon, O., Loewenbach, R., & Berzak, O. (2009). n-3 PUFA fortification of high n-6 PUFA farmed tilapia with linseed could significantly increase dietary contribution and support nutritional expectations of fish. *Journal of Agricultural and Food Chemistry*, *57*(6): 2249-2254.**

Farmed fish high in n-6 PUFA may undermine fish nutritional expectations and intake recommendations for n-3 PUFA requirements and exacerbate rather than improve already high n-6/n-3 PUFA diets. Dietary contribution of fish fortification by linseed-based n-3 PUFA was evaluated. Mango tilapia (12 months old) with high n-6 PUFA (21.8 FA%, n-6/n-3 ratio 4.6:1) were fed standard/control (T(C)) or linseed-supplemented (5%, T(5%); 7%, T(7%)) feed for 61 days regular-growth and 120 days stock-growth (to 650 g). Compared to T(C), n-3 PUFA increased in T(5%) 46% and T(7%) 58%; ALA in T(5%) increased 100% and T(7%) 167%; EPA+DHA in T(5%) increased 14% and T(7%) 23% ($p < 0.05$); n-6 PUFA/LCPUFA were unchanged. T(7%) EPA+DHA 168 mg/100 g of raw fillet is comparable to current American intake and Dietary Reference Intakes; controlled cooking preserved approximately 90% EPA+DHA. n-6/n-3 ratios decreased 16-38% in total PUFA to 2.3:1 and in LCPUFA to 0.61:1. Linseed supplementation could improve tilapia n-3 PUFA/LCPUFA, ameliorating n-3 PUFA scarcity and unexpectedly high fish n-6 PUFA content, potentially making a significant nutritional contribution.

**Singh, E.R.L., (2005). *The effects of integrated farming system on the productive and reproductive performances of parent muscovy ducks and Nile tilapia (Tilapia niloticus) biomass.* MSc (Animal Science) thesis. Suva: School of Agriculture, University of the South Pacific.**

The Integrated Farming System (IFS) is a production system that combines two or more, normally separate fanning systems together, thereby facilitating synergism between the different subsystems in a farming system complex. Using a duck-fish-crop IFS, this study investigated selected performance and reproductive traits of muscovy ducks during a production cycle and the growth potentials of Nile tilapia (Tilapia niloticus), including pond water dynamics (chemical and physical composition). The intensive or non-integrated (NIFS) farming system of duck and fish production served as the control. The feed given were: 12% crude protein for the ducks in the IFS, and 12% and 15% crude protein for ducks in the NIFS. The fish in the NIFS were fed ad libitum, while the fish in the IFS were given 50% less ad libitum feed. The results from the cunent study indicated that the ducks in the IFS consumed on the average 24% less feed compared to the ducks in the NIFS, and the trend for feed intake were: the 12%-CP IFS group < 15%-CP NIFS group < 12%-CP NIFS group ($P<0.05$). In contrast, the trend for reproductive performances as determined by percent hen-day, fertility and hatchability were: the 12%¬CP IFS group > 15%-CP NIFS group > 12%-CP NIFS group ($P<0.05$). However, production systems (IFS and NIFS) and dietary protein levels (12% and 15%), had no significant effects on egg sizes, live-weight of the ducklings at hatch, feed intake and post-hatch growth to 2 weeks of age ($P>0.05$). The fish in the IFS pond were significantly heavier and longer than the NIFS group, even though the IFS group were given 50% less feed than the NIFS group ($P<0.05$). At 20 weeks of age, fish yield were, 0.21 kg/m2 and 0.18 kg/m2 in the IFS and NIFS ponds respectively (PO.05). The total biomass (fish number * fish weight kg) were, 8.9 kg and 7.0 kg for the IFS and NIFS ponds respectively or 26.5% more biomass in the IFS pond compared to the NIFS pond. The concentrations of total dissolved solids, ammonia, chemical oxygen demand (COD), biological oxygen demand (BOD) and pond water temperature (oC) were higher in the IFS pond than the NIFS pond. The superior performances of the ducks in the IFS were attributed to the "un-audited" or diverse nutrient-rich sources in the scavenging areas of IFS that were readily available to the ducks. Similarly, the superior performances of the fish in the IFS were attributed to the nutrient contributions from the duck droppings which promoted algal growth or 'plankton bloom' as additional protein feed sources for the fish.

http://www.reefbase.org/download/download.aspx?type=10&docid=A0000005076_1

**Su'a, T., Nandlal, S. & Hair, C. (2009). *Experimental stocking and community management of tilapia in Lake Satoalepai, Samoa.* ACIAR Mini-Project FIS2001/ 075: Sustainable aquaculture development in the Pacific Islands Region and northern Australia.**

In Samoa, fishing has been a traditional practice, providing food, employment and economic benefits to many people. However, in recent years, it has been realized that fisheries resources, although renewable, are not infinite, and need to be properly managed. In 1999, a project by AusAID and the Samoa Fisheries Division (SFD) developed a framework for the better management of fisheries resources. This framework enabled SFD to reduce fishing pressure on the overexploited near-shore fishery resources by initiating aquaculture projects, which included the stocking of natural lakes and ponds. Subsequently, this mini project was developed by SFD in collaboration with Secretariat of the Pacific Community (SPC) under the ACIAR-funded project, 'Sustainable aquaculture development in the Pacific Islands Region and northern Australia'. They worked with the local communities of Matautu District on Savaii Island, Samoa and the goal was to increase fish production through restocking Oreochromis niloticus fingerlings in Lake Satoalepai (Samoa), and by managing these stocks through community co-management. This also provided an opportunity to improve skills of Samoa Fisheries Department (SFD) staff for tilapia restocking including hatchery operations, fingerling grow out and transport.

http://www.spc.int/coastfish/News/Lettre_Info/121_F/Lettre_Info_12_1.pdf

**Teri, J. & Pickering, T. (2009). *Productivity and constraints in tilapia fish and freshwater prawn aquaculture in Fiji.* ACIAR Mini-Project MS0507.**

The pace of development in Fiji freshwater aquaculture has been slower than expected. The main objective for the study which this report is based on was to find out the reasons by gathering evidence on farm performance, and on farmers' perceptions of problems. Fiji's freshwater focus is currently on tilapia *Oreochromis niloticus*, and prawn *Macrobrachium rosenbergii* aquaculture. All observations and measurements of soil and water quality fell within acceptable ranges, and there was no evidence that farm quality is a source of problems among these case studies. Evidence was found, however, that many farmers lack technical competence, which needs to be addressed by education and training. Farmers that have gone through some training are doing well. It was also found that infrastructure and support to farmers pose constraints, for example timeliness of tilapia fry deliveries, shortage of prawn post-larvae, the cost of feed, and the limited reach of Extension services and advice to farmers. Farmers that are located close to support services are doing well. Access to markets was a constraint for producers of live tilapia who wish to sell in bulk, but marketing was not a problem for prawn farmers. In Fiji there is huge potential for small-scale freshwater aquaculture to develop, and for farmers to improve their livelihood. Some tilapia farms are capable of becoming larger-scale commercial operators but are constrained by current dependence upon the limited live-fish sales outlets. Recommendations offered were: Extension support and advice to farmers should be improved; there should be tilapia product development (frozen, filleted, smoked) to add value and diversify marketing options; additional market outlets for live tilapia should be established; the green-water method of tilapia should be promoted for those who are unable or unwilling to buy feed and; collaboration between stakeholders (government departments, farmers association, regional and international organisations, donors, and education and research institutions) should be further encouraged and strengthened.

**Tonga Ministry of Fisheries & SPC. (2010). *Tonga Aquaculture Commodity Development Plan: 2010-2014.* Noumea, New Caledonia: Secretariat of the Pacific Community.**

The Aquaculture Management and Development Plan is a five-year "road map" for the future of aquaculture in Tonga. The plan is a tool that will assist government and local entrepreneurs as well as foreign investors on what type of aquaculture development they should pursue. Marine resources have always been a source of livelihood for the people of Tonga. In terms of export, agriculture has often been the bigger contributor. Fisheries, however, is becoming the "new frontier" in Tonga for export revenue, and aquaculture is seen as a way forward in terms of enhancing the economic contribution through employment, trade and skills development, and ensures food security for its people. Aquaculture is not new in Tonga, although it is new to most Tongans. Before this plan came into reality, the main aim of aquaculture in Tonga for over 20 years was to restock the reefs and assist the aquarium trade through culturing and rearing of giant clams. Now, the experiences and results of trials have encouraged the government and the Fisheries Department to move Tonga's aquaculture capacity into commercialization. The plan has outlined how licenses shall be allocated, categorized and managed and also provides avenues for communities to utilize their adjacent waters for aquaculture purposes. The current status of seaweed as a commodity: Wild stocks of the seaweed mozuku (*Cladosiphon* sp.) are exported to Japan depending on seasonal demand. On occasion, some spores are cultured to supplement the wild harvest and about 300–500 tonnes are farmed.

**Vasuca, J. (1996). *Tilapia farming in Fiji*, In: Present and future of aquaculture research and development in the Pacific island countries, pp. 167-182.**

The fisheries resources of Fiji include numerous marine and freshwater species. Overexploitation of the resources was a concern hence a Rural Aquaculture Programme was established to culture tilapia (*Oreochromis niloticus*). It provided additional source of protein as well as source of income. This paper presents briefly the history, present status, farming methods, problems and solutions of fish farming in Fiji. It discusses culture techniques and methods including site assessment, pond construction, pond preparation, stocking, feeding fish, harvesting and marketing.



**Watten, B.J. & Busch, R.L. (1984). Tropical production of tilapia (*Sarotherodon aurea*) and tomatoes (*Lycopersicon esculentum*) in a small-scale recirculating water system. *Aquaculture 41(3):271-283.***

An integrated fish and hydroponic tomato production system was evaluated for use in the US Virgin Islands. The system was constructed from readily available materials, and designed to minimize capital costs, energy and water use, and the technological skill needed for operation. Tilapia (*Sarotherodon aurea*) and tomatoes (*Lycopersicon esculentum*) were cultured outdoors for 181 days in a closed system containing 7.34 $m^3$ of water. Water quality suitable for fish production was maintained by aeration, biological filtration, sedimentation, hydroponic vegetable production and the addition of make-up water. Fish metabolites, wasted feed, and small quantities of inorganic fertilizers served as nutrient sources for tomato production. Fish survival (97.5%) and growth (2.54 g per day) were excellent with 63.6 kg of fish averaging 521 g each recovered at harvest. The total yield of ripe tomato fruit was 87.0 kg, of which 87.4% was marketable. The yield and quality of fruit produced hydroponically exceeded that produced under field trial conditions. Capital costs for the complete system were estimated to be US$612 (1979). Electrical energy and water use were 9.12 kWh $day^{-1}$ and 2.6% of the total volume per day, respectively. Cost and return projections indicate the system could be operated on a profitable basis in the US Virgin Islands.

**Whippy- Morris, C. (1994). *The potential for development of tilapia cage culture in Fiji*. MSc thesis. Suva: University of the South Pacific.**

An experiment on the growth of Tilapia (pure O. nxloticus and O.mossambicus x O.nxloticus hybrid) in cages in freshwater and brackish-water conditions was conducted for 120 days. Sixteen lm3 cages were each stocked with 100 individuals. Eight cages were placed in a freshwater pond of which four contained the pure and four contained the hybrid (giving the categories: freshwater pure and freshwater hybrid). Another eight cages of the same composition as mentioned above were placed in a brackish-water pond (15ppt, giving the categories: brackish-water pure and brackish-water hybrid) . The tilapia were given a pellet diet consisting of local agricultural by-products and fish meal with a 25% protein content. Mean daily weight gain (DWG) ranged from 0.85g to 1.08g, mean specific growth rate (SGR) ranged from 1.63% to 2.07% and mean food conversion rate (FCR) ranged from 3.07 to 4.00. Although there was no significant difference in DWG between pure and hybrid tilapia between treatments, a significant difference existed within treatments. There were no significant differences in SGR and FCR between pure and hybrids between and within treatments. The mean coefficient of variation of final body weight and length did not differ significantly between and within treatments. The final condition factor ranged from 1.77 to 1.90 and differed significantly between treatments but not within treatments. Final biomass ranged from 10.2kg/m3 to 13.1kg/m3 and percentage recovery ranged from 98.3% to 100%. There was 100% survival in all categories except the brackish-water pure. There were more females than males in all categories except the freshwater hybrid.

http://www.reefbase.org/download/download.aspx?type=10&docid=A0000004786_2

**Aiura, F.S., Carvalho, M.R.B., Viegas, E.M.M., Kirschnik, P.G & Lima, T.M.A. (2008). Nile tilapia (Oreochromis niloticus) preservation by means of dry salting and saturated brine. *Arquivo Brasileiro De Medicina Veterinaria E Zootecnia, 60*(6): 1531-1537.**

The processes of salting of Nile tilapia fillets (Oreochromis niloticus) submitted to saturated brine and dry salting were observed, and some characteristics that indicate the quality of the product during the storage were evaluated. The brine saturated process was followed up to 156 hours and the dry salting was followed up to 96 hours. When the salting finished, fillets were stored for 45 (dry salting) and 60 days (saturated brine), respectively. The highest values for chloride in fillets (14%) were reached within 72 hours in brine salting and 36 hours in dry salting. The tilapia fillets salted in brine kept the proper characteristics of the product for a period of 45 days and the fillets submitted to dry salting showed low moisture ratios (6%) and a high concentration of lipids (4.6%). Thereby, it is only recommended the salting process in saturated brine to be used as a mean of conservation for Nile tilapia fillets.

**Ali, A., Ahmadou, D., Mohamadou, B.A., Saidou, C. & Tenin, D. (2011). Influence of traditional drying and smoke-drying on the quality of three fish species (*Tilapia nilotica, Silurus glanis and Arius parkii*) from Lagdo Lake, Cameroon. *Journal of Animal and Veterinary Advances 10*(3): 301-306.**

Traditional fishing and fish processing are a very important activities around the Lagdo lake, Cameroon. This study was carried out to investigate the influence of traditional fish processing on the nutritional and microbiological qualities. To this effect, some physico-chemical characteristics (moisture, proteins, fats, TBA index, total ash, minerals) were determined for fresh, smoked-dried and sun dried flesh of three fish species (Tilapia nilotica, Silurus glanis and Arius parkii) while food-spoilage and pathogenic microorganisms (Escherichia coli, Staphylococcus aureus, fecal streptococci, sulfite-reducing clostridia and moulds) were screened on the same samples. Results showed that moisture content varied between 81.49±0.35 and 84.33±1.28 g/100 g for fresh fish; between 7.58±1.13 and 8.95±1.73 g/100 g for smoked-dried fish and between 11.5±0.71 and 14.06±2.11 g/100 g for sun-dried fish. For total ash, values as high as 8.13±1.55-9.86±0.24 g/100 g were recorded in smoked-dried fish while much lower values were obtained for fresh fish. With regard to protein contents, fresh fish had lower amounts between 18.81±1.55 and 21.23±1.50g/100 g while smoked-dried had the most important protein content between 69.10±2.94 and 75.72±3.66 g/100 g. All fresh fish samples showed lower fat contents than sun-dried and smoked-dried samples. Most minerals were significantly increased by sun-drying and smoking-drying. All samples appeared to be of poor microbiological quality since Escherichia coli, Staphylococcus aureus, fecal streptococci, sulfite-reducing clostridia and moulds were detected at concentrations above recommended norms.

http://www.medwelljournals.com/fulltext/?doi=javaa.2011.301.306

**Ardjosoediro, I. & Goetz, F. (2007). *A value chain assessment of the aquaculture sector in Indonesia.* Jakarta, Indonesia: USAID.**

The value chain (VC) assessment is the first step to understand and to identify opportunities and constraints in the aquaculture sector in Indonesia. This assessment provides a basis to evaluate needs and capacity to respond to market demands. AMARTA's technical approach encompasses the identification and strengthening of successful firms and dynamic key actors within the value chain which will serve as models to catalyze improvements of other firms. The strength of AMARTA will be to facilitate among all actors in the aquaculture VC in areas with existing comparative advantages. The efficacy of AMARTA's interventions and support lies in the vertical and horizontal linkages among the VC participants such as the farmers, the processors, the buyers, the government and other donors in the sector. Indonesia is the biggest archipelago on earth, with some 17,508 islands, and a coastline of 81,000 km. However, Indonesia's seafood industry is still in its infancy compared to its Asian neighbors. The identified three target sub-sectors in the aquaculture industry are to increase and strengthen Indonesian Competitive Position in the Life Fish Grouper market, to improve and strengthen the Indonesian Shrimp Brand in the world and improving the Added Value of Freshwater Aquaculture products for the markets in the Jakarta region (estimated at 20 million people). The growing urban markets represent a market opportunity for fish farmers in the Java region by improving their fish products through value added processes, cold chain and linkages with supermarket market segments.

http://pdf.usaid.gov/pdf_docs/PNADL490.pdf

**Asita, A. (2000). Protection of smoke-dried fish from fungal infestation by wood smoke differing in mutagenic potencies. *Discovery and Innovation*, *12*(1-2): 85-87.**

Fresh water Tilapia Sp. and mud cat fish, Clarias gariepinus were oven-dried or smoke dried for seven hours with either of the wood smoke of abura, black afara, mahogany, red mangrove or white mangrove and exposed thereafter to infestation by fungi. With the Tilapia sp, the order of protective effectiveness was abura > mahogany = red mangrove > white mangrove = oven dried > black afara. The result for cat fish was oven-dried = mahogany = red mangrove > abura = black afara = white mangrove. When compared with results of work on the mutagenic potencies of these woods smoke, mahogany smoke was shown to be effective in protecting fish in addition to possessing relatively lower concentrations of some PAHs and mutagenic potency compared to smoke from the other woods.

**Bell, L.A.J., Fa'anunu, U. & Koloa, T. (1994). *Fisheries Resources Profiles: Kingdom of Tonga.* Forum Fisheries Agency Report 94/05. Honiara, SI: FFA.**

This report provides an overview of those major fisheries resources identified by the Ministry of Fisheries as important to the commercial, artisanal and subsistence fisheries sectors within the kingdom. With regards to tilapia, the report mentions in passing that a culture trial of mullet (*M. cephalus*), milkfish (*Chanos chanos*) and tilapia (*Oreochromis mossambicus*) was conducted in Sopu Lagoon starting in 1974. Located west of Nuku'alofa, Sopu Lagoon has an area of approximately 50 ha, and in earlier times was an extension of the Fanga'uta Lagoon (Ludwig, 1979). Good results were obtained for *C. chanos* in the 1974-1975 period but no further developments were made.

http://www.sprep.org/att/IRC/eCOPIES/Countries/Tonga/7.pdf

**Bell, L.A.J., Mulipola, A.P., Skelton, P.A., Sasi, T. & Matsunaga, Y. and Alefaio, F. (1997). *Comparative taste study on Nile tilapia (Oreochrmos niloticus) and marine fish in Samoa and Nauru.* FAO field document No. 3/1997. 29p.**

This study examined the acceptability of the Nile tilapia as a food fish by having the public evaluating its taste against those of other fish cooked in the same way. For this study, Nile tilapia was cooked in different traditional methods: boiled in coconut cream, baked in the

Samoan "umu" and smoked. The first two methods are common ways of cooking fish traditionally in Samoa. In addition, skipjack and bottomfish were also smoked the same way Nile tilapia was smoked. No other fish, except tilapia, was cooked in coconut cream but tasters were asked to compare its taste with other fish, such as reef fish. The results for tilapia cooked in coconut cream indicated that 62% of the respondents preferred Nile tilapia over other fish while the other 38% rated tilapia to be the same as other fish. For fish that was cooked in the Samoan "Umu", 61% of the respondents preferred tilapia over bottomfish (snappers), 33% rated both tilapia and bottomfish the same and only 6% preferred bottomfish over tilapia. The results obtained for fish that were marinated with garlic and curry and then smoked were that 64% of the responses rated bottomfish as their first preference, 30% rated tilapia as their first preference and only 6% rated skipjack as their first preference. For fish that were marinated in soy sauce and ginger and then smoked, about 48% of the respondents rated bottomfish as the first preference, about 46% rated tilapia, as their first preference and only about 6% preferred skipjack over the other two.

http://www.fao.org/docrep/005/AC895E/AC895E00.htm

**Chamberlain T., Titili G., Novaczek I. & Seeto J. (2001). *Seafood processing*. Suva, Fiji : University of the South Pacific. Community Fisheries Training Pacific Series 6.**

The majority of Pacific Island countries rely on the sea as a major source of food. While women are not involved in offshore deep sea fishing, they are active in collecting and gleaning shellfish and other edible sea species from the nearshore areas and inside the reef. Women also prepare fish either for sale or home consumption. In this preparation process, women are involved in cleaning, gutting, cooking and selling various seafoods. In many atoll countries, women are also involved in the preservation of seafood by drying or smoking. In view of women's role in fisheries activities and the importance of seafood in the region, it is vital that women learn not only the correct handling methods for seafood, but also how to use marine resources wisely for the future. This manual is part of the Community Fisheries Training Series, and is designed to meet the wide need for community fisheries training in the Pacific, particularly for women to improve their skills in small-scale fisheries activities.

http://www.spc.int/DigitalLibrary/Doc/FAME/Manuals/Chamberlain_01_SeafoodProcessing.pdf

**Chinivasagam, H.N. & Etoh, S. (1985). *Vacuum pouch product development in Sri Lanka. Part 1: Processing. FAO* fisheries report.**

Studies related to the processing technology and storage characteristics of heat sterilized, vacuum-packed fish were carried out with the view of introducing the product as a substitute for imported canned fish. The present study deals with the processing aspects related to herring (*Amblygaster sirm* ), sardines (*Sardinella longiceps* ), tilapia species, milkfish (*Chanos chanos* ), tuna and flying fish (*Exocetus sp.*) in chilli/tomato sauce and brine. Laminated-O-Nylon, C-polypropylene was used as the packing material. The shelf life and some organoleptic aspects of the product during storage of vacuum packed herring and sardines is discussed.

**Cortesi, M.L., Panebianco, A., Giuffrida, A. & Anastasio, A. (2009). Innovations in seafood preservation and storage. *Veterinary Research Communications, 33*(1): 15-23.**



The increasing amount of farmed fish cannot be easily absorbed by the market as only fresh fish. The production and promotion of value-added fresh and processed fish products, which could fulfill consumers' present demands, may represent a solution to this problem. The aim of this paper is to review some of the most recent technologies, such as surface decontamination, use of "natural" additives and compounds, active packaging, used or experimented with to prolong shelf life, while ensuring the safety of fresh fish and fishery products.

**Costa-Pierce, B.A. (2007). *A market-driven, social ecological approach to planning for sustainable aquaculture: a case study of tilapia in Fiji*, In B.A. Costa-Pierce (ed.). Ecological aquaculture: the evolution of the blue revolution. Oxford, UK: Blackwell Science. 27p.**

The social, cultural and economic aspects of expanding tilapia (*Oreochromis mossambicus*) aquaculture production in Fiji were weighed; then the current and future demands (volume and price) for domestically produced tilapia were assessed in order to make recommendations on technological and development needs (based upon market information) for sustainable tilapia aquaculture in Fiji. Data were obtained from secondary sources as well as from a fish marketing survey involving 31 respondents (17 fish producers/sellers, 8 butchers, 4 roadside stalls, and 2 up-market fish stores). Most fish in Fiji are marketed through outlets, not in city/town centres, and the domestic market demand for tilapia is currently small. It is projected that domestic tilapia farmers in Fiji could safely expand domestic tilapia production from the current 122 mt with an additional 58-66 mt to total 180-188 mt by 206 (an expansion of 6-7 mt/year) to fill the predicted gap in tilapia-like reef fish marketed as fresh. There is less fish available on the market during the months of January to March (cyclone season), and there was some (but not significant) trend of higher fish prices during this period. There was no strong price-size relationship of demand. Current prices for whole tilapia are in the range of the most preferred reef species ($F2.50-5.50/kg). Tilapia prices could not be increased much further unless resource constraints increase with preferred reef fish species or a new period of economic prosperity occurs and people have more money to buy fish. It is recommended that the Fijian government develop a phased, three-step tilapia aquaculture development plan to: emphasize the domestic production sector by enhancing market opportunities; subsidize development and feed costs of a single farm that would produce fresh fillets for the high-end market; and subsidize development and operational costs for a small number of commercial farms.

**Costa-Pierce, B.A. (1998). Market-driven tilapia aquaculture development: results from a domestic and export marketing and industry study for Fiji. *Aquaculture '98 Book of Abstracts*, pp.122.**

The main objectives were to investigate tilapia industry status in Fiji, its domestic market, and export markets on the US west coast. A market survey was used to structure interviews with 23 buyers of seafoods based in Suva and surrounding areas and with 24 seafood buyers/brokers in Honolulu, Los Angeles, and San Diego. The Mozambique tilapia (Oreochromis mossambicus) was imported to Fiji in the 1950's and today is one of the most important protein sources in Fiji, called "maleya". Over 80% of rural people surveyed fishing in estuarine/riverine areas reported targeting "maleya". Tilapia fishing was dominated by women who caught fish at 12.7-13.9 kg/hour. In 1996, there were 172 tilapia farms growing Nile tilapia (O. niloticus), and national production was estimated at 122 tons. Smallholder farms produced 74 tons and a semi-commercial sector producing 48 tons. Gross value increased from F$204,000 in 1995 to F$366,000 in 1996 (US$ 1.40/F$1.00).

There was a dramatic change in the seafood marketing structure in Fiji from 1978 to 1995. In 1978, half of the sales passed through municipal markets and the other half to "outlets". By 1995, only 13% were sold at municipal markets and 87% marketed in "outlets". Tilapia has a similar size and appearance to the most preferred reef fish in Fiji. Seller interviews and secondary data gave a current estimate of demand for small reef fish of similar size and appearance to tilapia on Viti Levu of 66-324 tons per year. Five product forms of Fiji tilapia suitable for export to the USA market were investigated: (1) whole, fresh, (2) whole, frozen, (3) fillet, frozen, (4) fillet, fresh, and (5) fillet, fresh, "Izumi Dai". Largest demands in both Hawaii and California were for fresh fillets. Significant market competition for volume and price were found for all forms except for "Izumi Dai". While Fiji has superb natural resources for exporting tilapia: (1) the lack of availability of a proven commercial feed, (2) the high projected costs of feed manufactured locally, and (3) the high costs of air freight make a commercial venture into the US export market for high value fresh fillets neither technically nor economically feasible. A partial benefit-cost analysis projected sale prices of exported fresh fillets at US$ 6.71-7.50 per kg but landed costs were estimated to exceed $6.45 per kg. Air freight and feed costs were far too expensive for Fiji to be competitive. It was recommended that Fiji develop applied, market-driven tilapia aquaculture technology with a focus on its local hotel markets for high quality, fresh fillet tilapia to "ease into the export market" and expand its domestic, rural production sector to 300 tons/year by 2000.

**Dale, N.M., Zumbado, M., Gernat, A.G. and Romo, G. (2004). Nutrient value of tilapia meal. *J. Appl. Poult. Res. 13*:370–372.**

By-products of the processing of tilapia are beginning to appear as feed ingredients. Eight samples were obtained and evaluated for nutrient content so as to provide the nutritionist with a baseline of information with which to consider possible use of this ingredient. At the present time, there is considerable variation in the composition of tilapia meals from different sources. Nutrient composition ranged from: CP, 52.5 to 57.8%; TMEn, 2,374 to 3,269 kcal/kg; and Ca, 5.2 to 10.6%. As significant variation was noted in levels of most nutrients, confirmatory analysis on specific samples is recommended prior to general use in formulation. Due to the popularity of tilapia as a human foodstuff, increasing amounts of rendered tilapia meal are becoming available. Proximate composition, ME, amino acid composition, pepsin digestiblity, mineral composition, and fatty acid analysis of tilapia meal are reported for those considering the use of this ingredient in formulated feeds.

http://japr.fass.org/cgi/reprint/13/3/370.pdf

**Daramola, J.A., Fasakin, E.A. & Adeparusi, E.O. (2007). Changes in physicochemical and sensory characteristics of smoke-dried fish species stored at ambient temperature. *African Journal of Food Agriculture Nutrition and Development, 7*(6).**

This study assessed the comparative changes in the physical and chemical components of five different species of smoked freshwater fish: Bony tongue, *Heterotis niloticus*, African carp, *Labeo coubie*, Snake fish, *Parachanna obscura*, Nile Tilapia, *Oreochromis niloticus* and African mud catfish, *Clarias gariepinus* during storage. The fish were smoke-dried to average moisture content of 10.41 ± 0.02% and stored. Fish were packaged in black polythene bags and kept in perforated plastic containers. The fish were left in the plastic baskets for 56 days at ambient temperature (25-32°C). Samples of fish were assessed weekly for physical attributes such as colour, fragmentation, odour, taste and texture. Proximate composition was assessed using changes in moisture content, crude protein, lipid and ash content. Biochemical indexes carried out were: Total Volatile Nitrogen (TVN), pH, Peroxide Value (PV) and Free Fatty Acid (FFA) levels. There was a general decline in physical attributes i.e. colour, fragments or cracks, odour, taste and texture of fish during storage. Fluffy woolly mat of moulds were noticed on the *Clarias gariepinus* from the 5th week of storage. There was a significant (P <0.05) colour change in most species as from the 6th week. During this study, the moisture content increased weekly in the five smoked fish species from the initial average of 10.41±0.02%. This could be attributed to the difference in the moisture of the smoked fish relative to the surroundings. *Oreochromis niloticus* and *Heterotis niloticus* had the best taste value. Apart from *Parachanna obscura*, the other fatty species, *C. gariepinus* and *L. coubie* became less firm as the weeks progressed. There were significant changes (P <0.05) in most of the physical and chemical characteristics except odour from the 6th week (42 days) of storage. There were also significant differences (P <0.05) between the initial and final values of the proximate and chemical constituents of the different species of fish. The study showed that keeping quality of smoked fish under ambient conditions decreases with increase in length of storage.

http://www.bioline.org.br/request?nd07049

**De Silva, D.A.M. (n.d). Value chain of fish and fishery products: origin, functions and application in developed and developing country markets. Rome: FAO.**

This report considers the drivers and governors of change on the demand function of fish and fishery products. It looks at the following factors in detail and how they affect the demand of fish and fishery products. Some of the factors under consideration are: demographics, consumer preference, buyer specification, certification, price point and service, technology, regulatory change, market access, factor costs and distribution and retailing and economic growth trends.

http://www.fao.org/fileadmin/user_upload/fisheries/docs/VALUE_CHAIN-report1.doc

**Dhanapal, K., Reddy, G.V.S., Nayak, B.B., Basu, S., Shashidhar, K., Venkateshwarlu, G., & Chouksey, M.K. (2010). Quality of ready to serve tilapia fish curry with PUFA in retortable pouches. *Journal of Food Science*, *75*(7): 348-354.**

Studies on the physical, chemical, and microbiological qualities of fresh tilapia meat revealed its suitability for the preparation of ready to eat fish curry packed in retort pouches. Studies on the fatty acid profile of tilapia meat suggest fortification with polyunsaturated fatty acid (PUFA) to increase the nutritional value. Based on the commercial sterility, sensory evaluation, color, and texture profile analysis F(0) value of 6.94 and cook value of 107.24, with a total process time of 50.24 min at 116 C was satisfactory for the development of tilapia fish curry in retort pouches. Thermally processed ready to eat south Indian type tilapia fish curry fortified with PUFA was developed and its keeping quality studied at ambient temperature. During storage, a slight increase in the fat content of fish meat was observed, with no significant change in the contents of moisture, protein, and ash. The thiobarbituric acid (TBA) values of fish curry significantly increased during storage. Fish curry fortified with 1% cod liver oil and fish curry without fortification (control) did not show any significant difference in the levels of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), during thermal processing and storage. Sensory analysis revealed that fortification of fish curry with cod liver oil had no impact on the quality. Tilapia fish curry processed at 116 C and F(0) value of 7.0 (with or without fortification of cod liver oil) was fit for consumption, even after a period of 1-y storage in retort pouch. PRACTICAL APPLICATION: Tilapia is a lean variety of fish with white flesh and therefore an ideal choice as raw material for the development of ready to serve fish products such as fish curry in retort pouches for both domestic and international markets. Ready to eat thermal processed (116 C and F(0) value of 7.0) south Indian type tilapia fish curry enriched with PUFA and packed in retort pouch was acceptable for consumption even after a storage period of 1 year at ambient temperature.

**Ehizibolo, D.O., Chukwu, C.O., Chukwu, I.D., Muhammad, M.J., & Olabode, A.O. (2007). Occurrence of foodborne bacterial pathogens in smoked fish at retail level in Jos, Nigeria. *Nigerian Veterinary Journal*, *28*(1): 21-26.**

Sixty five (65) smoked fish samples (30 catfish and 35 Tilapia) were obtained form three retail market locations in Jos South, Nigeria, and screened for foodborne bacterial pathogens. Potential human pathogens were isolated from all the samples studied through culture, growth characteristics, morphological, physiological and biochemical reaction of substrates and enzyme activities. Organisms isolated include Staphylococcus aureus, 29 (44.6%), Listeria monocytogenes 6 (9.2%), Pseudomonas aeruginosa 7 (10.7%), Proteus mirabilis 5 (7.7%), Escherichia coli 1 (1.5%), Bacillus cereus 2 (3%) and Yeast cells 10 (15.4%). However, there were no significant differences (P>0.05) in the occurrence of the isolates and the markets sampled. This study reveals that smoked fish sold on the retail market in Jos, Nigeria could be a potential source of foodborne bacterial pathogens if not properly handled. Improvements in processing and handling are required, and the need for food borne bacterial disease surveillance is indicated.

**Fiji Islands Trade & Investment Bureau. (2009). *Fiji Islands: investment opportunities in the processed fish, fish products and processed seafood industry.* Suva, Fiji: FTIB Profile on processed fish and fish products.**

The fisheries sector contributed 2.3% to GDP in 2008 and generates $FJD134.2million of exports in 2008. Moreover, this sector is cited as being among the sectors in the economy demonstrating the highest growth potential. Incentives and concessions exist for investors, with a 200% deduction on capital expenditure for a period of 5 years W.E.F 2006 for all investors engaged in fisheries activity. Also, all inputs, components and accessories imported for utilization in production of a final product for export are exempt from payment of any duty under the Duty Suspension Scheme (DSS) or are eligible for drawback of duty under the Industrial Drawback Regulation. The profile notes that for the local market, opportunity exists for upstream processing and value adding in the production of fish fingers, fish cakes, fish burgers, fish sausages, fish paste, etc.

http://www.ftib.org.fj/resources/uploads/embeds/file/Processed%20Fish%20&%20Fish%20Producs(1).pdf

**Fitzsimmons, K. (2004). *Development of new products and markets for the global tilapia trade.* Proceedings of the 6th International Symposium on Tilapia in Aquaculture, Manila, Phillipines: 624-633.**

Tilapia production surged around the world during the 1990's and early 2000's. Tilapias are now the second most popular farmed fishes after the carps, with global production well over 1,526,000 mt in 2003. This has been accomplished by developing large consumer markets in North America and Europe, which are purchasing fish grown in tropical countries with year-round production and relatively low costs. These markets have evolved in a similar manner, starting with immigrant communities, moving into high cost, white tablecloth restaurants, then casual dining chains, hypermarkets and club stores and finally to traditional seafood counters and frozen foods of local groceries. With this rapid development in markets have come a variety of new product forms and commercial by-products. This has been a critical factor in the continued rise of tilapia in the ranks of popular seafoods and is a result of thoughtful marketing and product development, as well as increasing demands from retailers and consumers. A variety of product forms are described along with methodologies used to develop new markets for these products. By-products including leather goods, pharmaceutical products, and decorative objects made from tilapia scales are also described.

http://ag.arizona.edu/azaqua/ista/ista6/ista6web/pdf/624.pdf

**Fitzsimmons, K. (2008). *Tilapia product quality and new product forms for international markets.* Proceedings of the 8th International Symposium on Tilapia in Aquaculture, Cairo, Egypt, October 12-14.**

Egypt is the second greatest producer of tilapia products, after China. However, virtually all tilapia produced in Egypt is sold on domestic markets. Egypt, with its central location on the Mediterranean and extensive trade with the European Union and the States of the Arabian Peninsula, should be a major exporter of tilapia goods as well. The current constraints to tilapia exports are: 1) Production of tilapia in sub-optimal water conditions, 2) Lack of Best Management Practices (BMP's) for production conditions, 3) Lack of sufficient Hazard Analysis at Critical Control Points (HACCP) and International Standards Organization (ISO) approved processing plants, 4) Lack of value added capabilities (freezing, breading, packaging, etc.), 5) Lack of by-product industries. These constraints should be addressed through a mix of government and private actions. Development of demonstration projects with integrated aquaculture-agriculture documenting the significant benefits of using water for aquaculture before field crop irrigation is proposed. Training in use of international standards and examples of BMP's, Good Aquaculture Practices, and Quality Assurance programs are discussed. The rapid implementation of HACCP, Codex Alimentarius, ISO, and other international certification programs are proposed. Descriptions of the current state of the art of producing, harvesting, processing, and packaging are provided, along with plans of how best to introduce these technologies. Finally, several by-product industries including tilapia skin leather, pharmaceutical uses of fish collagens, decorative use of tilapia scales, and production of bio-fuels are described.

http://ag.arizona.edu/azaqua/ista/ISTA8/Fitzsimmons.pdf

**Irianto, G. & Irianto, H.E. (1997). *Post-harvest technology of Nile tilapia in Indonesia: a review. Asia Pacific Fishery Commission.* Summary report of and papers presented at the tenth session of the Working Party of Fish Technology and Marketing, Colombo, Sri Lanka, 4-7, June 1996: 71-83. [FAO Fish. Rep.].**

Some studies have been carried out to investigate possible utilization of Nile tilapia (*Oreochromis niloticus)* in Indonesia. Tilapia can be consumed as fresh fish and processed products. Icing is an effective method to keep the freshness and to extend the shelf life of tilapia. Tilapia meat has been processed into surimi, fish flour, fishburgers, fish balls, fish crackers, fish fingers, fish sausages, bread and noodles. Processing wastes can be utilized for fish meal. Tilapia waste meal, used in shrimp feed formulation, resulted in a good growth development of giant freshwater shrimp.

**Ismail, M.S. & Zain, A. (1978). Utilization of tilapia, a trash freshwater fish. *Proc. IPFC, 18*(3): 303-309.**

Fish is an important source of protein in South-East Asia but consumption is limited by price, supply, distribution and season, especially amongst the poor. Most fish comes from marine sources and, in Malaysia, fish from aquaculture form less than one percent of the total although there are 100,000 acres (40,000 ha) of freshwater bodies suitable for aquaculture, in West Malaysia alone. Tilapia is a tropical freshwater fish which is common and its vigorous breeding and growing capacity are such that it is considered a pest in aquaculture. It has no market value and no known commercial utilization in Malaysia. However, four acceptable products were developed using tilapia: (1) Fish sauce, produced by a rapid fermentation using Aspergillus oryzae ; (2) 'Pekasam', fermented with rice and consumed after frying or roasting in banana leaves; (3) Canned in tomato sauce; (4) Salted and dried. The protein content and quality of these products are discussed.

**Jamandre, W.E., Hatch, U., Bolivar, R.B. & Borski, R. (2011). *Improving the supply chain of tilapia industry in the Philippines.* In: Liping, L. & Fitzsimmons, K. (eds.). Better science, better fish, better life: proceedings of the ninth international symposium on tilapia in aquaculture. Corvallis, Oregon: AquaFish Collaborative Research Support Program.**

This study was designed to evaluate and develop an efficient tilapia supply chain to foster the development of viable fast food and supermarket purchases of tilapia from small-scale producers with the following specific objectives: **Phase 1 – Evaluation**: Develop tilapia supply chain maps for each market level, i.e., producer, wholesale, restaurant, supermarket and fast food stores to identify specific activities and services, key players, logistical issues, external influences, and flow of product, information and payment among market levels; Analyze tilapia supply chain performance for efficiency, flexibility and overall responsiveness; Identify areas for improvement in supply chain (i.e. behavioral, institutional and process); Provide recommendations to improve the tilapia industry, in general and specific supply chain items. **Phase 2 - Development Undertaking:** Design specific improvement measures based on the identified areas of improvement from Phase 1; Test the improvement measures in the market place, then assess and refine the improvement measures; Design and implement measures to ensure the sustainability of the improved supply chain of tilapia. Some recommendations in the report are: encourage the establishment of more nursery farms for better quality brood stocks while intensifying technology transfer to farmers for better health and management of tilapia; conduct market promotion activities highlighting the various niche opportunities of tilapia among growers and consumers; motivate the participation of small farmers in supply chains by setting up an incentive scheme through a mix of patronage refund and profit sharing; institutionalize an accreditation program for feed manufacturers, hatcheries, processors and the like to improve the quality assurance of products and services; and provide capital windows to improve facilities and reduce logistics and transaction costs in the entire supply chains of tilapia.

http://ag.arizona.edu/azaqua/ista/ISTA9/FullPapers/JamandrePhilippines.docx

**Kabahenda, M.K. & Husken, S.M.C. (2009). *A review of low-value fish products marketed in the Lake Victoria region*. Regional Programme Fisheries and HIV/AIDS in Africa: investing in sustainable solutions.The WorldFish Centre. Project Report 1974.**

The growth of commercial fisheries, especially Nile perch export, has resulted in reductions in fish stocks and availability of fish to populations in the Lake Victoria region. This decline in fish does not only threaten livelihoods of artisanal fisherfolk and processors but also threatens the nutrition and food security of populations in the region. As Lake Victoria's stocks of Nile perch (Lates niloticus) and tilapia continue to dwindle, artisanal fisherfolk are turning to low-value fish such as mukene (Rastreneobola Argentea) while artisanal processors are diverting to processing by-produts of filleting operations. This shift is desirable but does not seem to assure fish access to populations in the riparian counties. This review seeks to document the contribution of low-value fish products to the food and nutrition security of individuals living with HIV/AIDS and those at risk of malnutrition. Given the high prevalnce of malnutrition in the Lake Victoria region, there is need to regulate usage and trade in low-value fish products in order to improve access to fish among populations at high risk for malnutrition.

http://docs.mak.ac.ug/sites/default/files/Project%20Report%201974%20-%20.pdf

**Lal, S.N. (2005). Driti Women's Tilapia Project. *SPC Women in Fisheries Information Bulletin 15*: 23.**

In Bua's Driti village, Fiji, a tilapia farming venture led by a women's group, generated quite significant cash, leading to an investment scheme to assist village projects. Abandoned by the men's group after the supply of fingerlings from the government stopped, the women sought help from relevant institutions and farmed and marketed tilapia and prawns. The latest record of production was 2.6 tonnes of tilapia, which sold for FJD 9100 (December 2003).

http://www.spc.int/DigitalLibrary/Doc/FAME/InfoBull/WIF/15/WIF15_23_Nandlal.pdf

**Nketsia-Tabiri, J. (2004). Radiation decontamination and disinfestation of salted dried tilapia fish (koobi). *Ghana Journal of Agricultural Science 37*: 85-90.**

Salted dried tilapia (*Oreochromis niloticus*) fish locally called *koobi* was investigated with the view of establishing the effective radiation dose for controlling microbial and insect activity on the product. Total viable count (TVC) of market samples of *koobi* ranged between log 10 4.11 - 6.78 cfu/g, whilst mould and yeast count ranged between log 10 1.38-3.38 cfu/g. *Staphylococcus aureus* counts ranged between log 10 2.85 - 4.15 cfu/g. After 4 weeks' storage under ambient conditions, total viable count increased to log 10 7.5 ± 2.5 cfu/g. Significant reduction in total viable count was observed after treatment with gamma radiation. A least square regression fitted through the data points indicated that 1.3 kGy would be required to reduce the microbial population on the product by one log cycle. Insects and pink colonies of halophilic bacteria were observed on all the non-irradiated samples after 4 weeks' storage. Treatment with 3 kGy gamma radiation eliminated all insect forms, while microbial population was controlled with TVC ranging between log 10 1.9 ± 1.1 and log 10 2.7 ± 1.6 cfu/g throughout the 16 weeks' storage period. The proliferation of halophilic bacteria and subsequent appearance of pink colonies on irradiated *koobi* was suppressed until the 16th week. Irradiation, therefore, extended the shelf-life of *koobi* from 4 to 15 weeks.

http://www.ajol.info/index.php/gjas/article/viewFile/2083/10914

**Norman-Lopez, A. & Bjorndal, T. (2009). *The global market for tilapia – one or several.* Bergen: Institute of Research in Economics and Business Administration. Working Paper 10/09. 32p.**

Tilapia is one of the fastest growing aquaculture species in the world. It is produced and consumed in all continents and in more countries than most other species, making the market more heterogeneous than for other successful aquaculture species such as salmon and shrimp. This paper investigates the degree of market integration between tilapia from the three largest production regions, Asia, Africa and South and Central America. We consider differences in the production methods, transport costs and qualities of these regions and determine whether tilapia products from different producers can essentially be considered the "same" product. This is important if the rapid worldwide development of farmed tilapia and its future development prospects are to be better understood.

http://bora.nhh.no/bitstream/2330/2184/1/A10_09.pdf

**Odoli, C.O. (2009). Optimal storage conditions for fresh farmed tilapia (*Oreochromis niloticus*) fillets. MSc (Food Science). Department of Food Science and Nutrition, Faculty of Science, University of Iceland.**

The main aim was to establish optimal storage conditions for fresh tilapia fillets, by determining its shelf life from the sensory and microbiological evaluation, as well as monitoring its physical-chemical properties. With this intent, Nile tilapia (*Oreochromis niloticus*) farmed in recirculation aquaculture system was filleted and packaged in 100% air and 50% $CO_2$: 50% $N_2$ MA prior to storage at different temperature; 1˚C and -1˚C. Initial samples from filleting (control d0) were also evaluated for comparison. This report further describes the development of a Quality Index Method (QIM) scheme and a sensory vocabulary for fresh and cooked tilapia fillets accordingly and application in a shelf life study. The application of the QIM scheme for tilapia fillets showed a linear relationship between QIM scores and storage time with significant correlations ($r > 0.93$) for all sample groups experimented in the main study. The results from sensory analysis of cooked samples as well as microbial growth indicated fillets packaged in 100% air had a shelf life of 13-15 days during storage at 1˚C and 20 days during storage at -1˚C. At the end of shelf life in 100% air packaged groups, TVC and pseudomonads counts reached log 7 CFU/g in flesh. In MA packaged fillets, the lag phase and generation time of bacteria was extended and recorded counts below the limit for consumption (< log 4 CFU/g) up to 27 days of storage at both 1˚C and -1˚C. However, MA packaging affected negatively on fillets colour characteristics soon after packaging (as from d6) yet colour is an important indicator of quality and a major factor in influencing retail purchase decisions. Chemical analyses (TVB-N and TMA) were not good indicators of spoilage of tilapia fillets in the present study. Physical parameters (drip and water holding capacity) were observed to be a function of storage temperature and atmosphere, with storage at 1˚C as well MA recoding low quality (undesired) scores. 100% air packaged fillets stored at -1˚C recorded superior quality characteristics during storage as well as extended shelf life. For that reason, it is plausible that 100% air packaging at -1˚C storage temperature is the optimal storage conditions for fresh tilapia fillets.

http://www.unuftp.is/static/files/rannsoknarritegrdir/Cyprian%20Msc%20%20thesis%20version-1.pdfv



**Parakulsuksatid, P., Patchimaporn, U. & Sanam, C. (2009). *Effects of gaseous ozone on the physico-chemical and microbiological properties of dried Nile Tilapia.* Proceedings of the 47th Kasetsart University Annual Conference, Bangkok (Thailand), 17-20 Mar 2009.**

Staphylococcus sp., Bacillus sp., and Lactic acid bacteria were found in sun dried Nile Tilapia that generally sold in the market. Thus, it would be a great benefit to ensure the effect of gaseous ozone on the physico-chemical and microbiological properties of dried Nile Tilapia. The fish meats were dried at two temperatures (40 and 50 deg C) for 1 hr and after that fumigated with ozone (1, 3, and 5 ppm) for 30 min, circled this process until the water activity reached to 0.85. The results revealed that the application of gaseous ozone could decrease the total bacterial and yeast/mould counts and TVB-N values in dried fish. In addition, drying at 50 deg C increased the L*, b*, hue, and chroma, and TBA values of samples.

**Pohajdak, B., Mansour, M., Hrytsenko, O., Conlon, J.M., Dymond, L.C. & Wright, J.R. Jr. (2004). Production of transgenic Tilapia with Brockmann bodies secreting [desThrB30] human insulin. *Transgenic Research 13*: 313–323.**

Tilapia are commercially important tropical fish which, like many teleosts, have anatomically discrete islet organs called Brockmann bodies. When transplanted into diabetic nude mice, tilapia islets provide long-term normoglycemia and mammalian-like glucose tolerance profiles. Using site-directed mutagenesis and linker ligation we have ''humanized'' the tilapia insulin gene so that it codes for [desThrB30] human insulin while maintaining the tilapia regulatory sequences. Following microinjection into fertilized eggs, we screened DNA isolated from whole fry shortly after hatching by PCR. Positive fish were grown to sexual maturity and mated to wild-types and positive F1's were further characterized. Human insulin was detected in both serum and in the clusters of b cells scattered throughout the Brockmann bodies. Surrounding non-b cells as well as other tissues were negative indicating b cell specific expression. Purification and sequencing of both A-and B-chains verified that the insulin was properly processed and humanized. After extensive characterization, transgenic tilapia could become a suitable, inexpensive source of islet tissue that can be easily mass-produced for clinical islet xenotransplantation. Because tilapia islets are exceedingly resistant to hypoxia by mammalian standards, transgenic tilapia islets should be ideal for xenotransplantation using immunoisolation techniques.

**Prasad, B.C. (2006). *Trade and environment dimensions in the food and food processing industries in Asia and the Pacific: a country case study of Fiji*. Suva, Fiji: UNDP.**

The three most important food and food processing industries in Fiji are sugar, fish, and fruits vegetables and root crops. In a 2001 Asian Development Bank (ADB) study on the contributions of the fisheries sector to the economies of the Pacific Island Countries, it was estimated that in Fiji, the catches by subsistence fishing are worth around US$24,675,061, by coastal commercial fishing US$15,231,519, and by locally based offshore fishing US$25,639,724. The same study also calculated that this fishing is responsible for about 2.4% of Fiji's GDP. Because fish processing and other post-harvest activities are considered in other sectors of Fiji's economy for GDP calculation purposes, the contribution of fisheries to the economy of Fiji is substantially larger than the 2.4% from fishing alone. The 1996 census showed that fishing provides jobs to 2.22% of the 280,505 people formally and informally employed in the country. Data from the Fiji Islands Bureau of Statistics show that exports of fishery products currently account for about 9% of the total domestic exports from the country. The report mentions that the government is providing suitable, technologically appropriate, safe and cost effective fishing vessels, particularly for industrial fisheries segment to promote and expand sustainable competitive exports of living marine products. It has also provided assurance of adequate airfreight for export production and is encouraging local value adding and down-stream processing with the aim of maximizing the value of marine products.

**Quang, N.H. (2005). *Guidelines for handling and preservation of fresh fish for further processing in Vietnam.* Reykjavik, Iceland: The United Nations University.**

Fish from catching has an important role in international fisheries as well as in developing countries like Vietnam. Therefore maintaining good quality in fish raw material is necessary. This project focuses on how to handle and preserve the fish especially during the process from catching the fish at sea to landing and transporting the fish to the processing plant. This project establishes guidelines for these activities. In addition some experiments were carried out to determine the insulation ability of different types of fish boxes used for storing fish and to validate the guidelines by evaluating the fish quality during ice storage in the worst and best scenario cases. Based on data collected in Vietnam as well as fish preservation techniques in Iceland, problems in the handling and preservation process in Vietnam are pointed out and solutions presented. Choosing the appropriate fish containers like boxes or tubs is considered one significant factor contributing to fish freshness and quality. The Sæplast insulation plastic boxes or tubs are very suitable containers, which can possibly be used in the Vietnamese fisheries industry in the near future.

http://www.unuftp.is/static/fellows/document/quang05prf.pdf

**Reddy, N.R., Schreiber, C.L., Buzard, K.S., Skinner, G.E. & Armstrong, D.J. (1994). Shelf life of fresh tilapia fillets packaged in high barrier film with modified atmospheres. Journal of food science, 59(2): 260-264.**

The effect of modified atmospheres (MAs) (75% $CO_2$:25% $N_2$; 50% $CO_2$: 50% $N_2$; and 25% $CO_2$: 75% $N_2$) and 100% air on shelf life of fresh tilapia fillets packaged in high barrier film bags was evaluated at refrigeration temperature (4.0°). Fillets packaged in 100% air spoiled after 9 days, as indicated by sensory characteristics, and had increased surface pH, TMA content, K-value and high microbial counts. When levels of $CO_2$ were increased from 25 to 75% in the package atmosphere, the shelf life of MA-packaged tilapia fillets was extended 4–21 days more than that of fillets packaged under 100% air. Although fillets packaged under 75% $CO_2$:25% $N_2$ were judged by sensory characteristics to be acceptable for more than 25 days, their K-value was high (93.1%). K-values were independent of spoilage and correlated only with length of storage of the MA-packaged fillets.

**Richards, A., Lagibalavu, M., Sharma, S. & Swamy, K. (Comp.). (1994). *Fiji Fisheries Resources Profiles.* Forum Fisheries Agency Report 94/4. Honiara, SI: FFA.**

This report provides an overview of the fisheries and marine resources identified as being of importance to the commercial, artisanal and subsistence fisheries sectors in Fiji. The main purpose is to provide the basic information required to assess the current levels of exploitation, and to identify the research and management requirements for future developments. With regards to tilapia, there are several strains of it in the country, all of which were introduced from other countries. Originally introduced as pig feed, it was in the



1950s that tilapia was suggested as potential human food. From 3 fully functional private ponds in the Rural Aquaculture Programme (RAP) in 1982, co-operative groups and individuals have established a decade later nearly 70 fish farms in Fiji's Naitasiri Province alone. Thirty farms are operated by small groups, the rest by individuals, and an average of 5.7 mt valued at FJD17,000 (about USD11,300) is harvested each year. Batches of 200-300 tilapia sell quickly in retail markets for approximately FJD3.00-4.00 per kg, a price comparable or slightly higher than the price paid for several species of reef fish. However, part of this success is due to government subsidies, e.g. *O. niloticus* fingerlings are supplied to farmers free of charge.

http://www.sprep.org/att/IRC/eCOPIES/Countries/Fiji/9.pdf

**Shouchun Liu, Wen Fan, Saiyi Zhong, Changwei Ma, Pinglan Li, Kang Zhou, Zhaohui Peng and Meijun Zhu. (2010). Quality evaluation of tray-packed tilapia fillets stored at 0°C based on sensory, microbiological, biochemical and physical attributes. *African Journal of Biotechnology 9*(5): 692-701.**

The quality deterioration of tray-packed tilapia (genetically improved farmed tilapia strain of *Oreochromis niloticus*) fillets stored at 0°C were studied by integrated evaluations of sensory, microbiological, biochemical and physical analysis, in order to expound the mechanism of fish spoilage and develop the most reliable indicators for quality assessment. The results showed that four quality index as *Pseudomonas* counts, total volatile basic nitrogen (TVBN), cadaverine (CAD) and K value were highly correlated ($r > 0.90$) with storage time and sensory acceptability. Protein degradation was visible on SDS-PAGE when microbiological load exceeded 6 log cfu/g. Thiobarbituric acid reactive substances (TBARS) value remained at a very low level throughout the storage, suggesting low lipid oxidation in muscle. Hardness decrease tested by texture machine was consistent with texture softening of fillets in the sensory evaluation. Considering fish freshness and microbiological safety, the shelf life of tilapia fillets stored at 0°C was approximately 10 - 12 days.

http://www.academicjournals.org/AJB/PDF/pdf2010/1Feb/Liu%20et%20al.pdf

**Venugopala, V., Dokea, S.N. & Thomasa, P. (1999). Radiation processing to improve the quality of fishery products. *Critical Reviews in Food Science and Nutrition 39*(5): 391-440.**

Extensive investigations, worldwide, in the last 4 decades have shown the benefits of radiation processing for the preservation and microbial quality improvement of seafoods. In the present review, the various factors determining the quality of seafoods are first presented. The basic principles underlying the effects of ionizing radiation and specific effects on food constituents such as proteins, amino acids, lipids, vitamins, and tissue enzymes are discussed. Data on radiation processing of seafoods are reported and discussed with respect to shelf life enhancement under refrigeration by control of bacteria causing spoilage, radiation sensitivity of pathogenic microorganisms and parasites of public health significance and their elimination in fresh and frozen fishery products, control of insect disinfestation in dried fishery products, influence of irradiation on nutritional and sensory quality attributes, detection of irradiation treatment, economics, and international status.

**Weinberger, K. & Lumpki, T.A. (2006). *High value agricultural products in Asia and the Pacific for small-holder farmers: trends, opportunities and research priorities*. AVRDC: The World Vegetable Centre.**

The majority of the world's poor are found in the Asia Pacific region, despite vast improvements over the past decades. Eight hundred million people in Asia and the Pacific live on less than a dollar per day, two-thirds of the global poor (IFAD, 2002). This paper aims to highlight the current and the future role of HVAP (high value agricultural products) in agriculture and trade in Asia and the Pacific; identify opportunities and constraints for small-holders participation in these markets and highlight lessons learned from past research and development efforts in Asia and the Pacific.

http://www.fao.org/docs/eims/upload/210973/regional_ap.pdf

**Wiratchakul, S., Wirulhakul, P., Kongpan, O., Wiratchakul, J., Chaoruangrit, A. & Thawornchinsombat, S. (2000). Surimi manufacturing from tropical tilapia (Nile tilapia, Oreochromis niloticus, Linn). *Khon Kaen Agriculture 28*(3): 146-159.**

A study of the functional properties and color of surimi gels prepared from 6 and 48 hours iced storage tropical tilapia (Nile tilapia, Oreochromis niloticus, Linn) at three different thermal setting conditions: (1) 40`C 60 min followed by 90`C 40 min, (2) 60`C 60 min followed by 90`C 40 min, and (3) 90`C 40 min. Surimi gel prepared from 48 hours iced storage tilapia possessed higher gel-strength or hardness than surimi gel prepared from 6hrs iced storage tilapia ($p<0.05$) but no effects on cohesiveness and gel color ($p>0.05$). The optimum thermal setting condition for tilapia surimi appeared to be at 40`C set for 60 min followed by 90`C cook for 40 min. Quality of tilapia surimi tended to decrease during longer frozen storage (-20+/- 2`C). However, quality is still be accepted quality at 12 months frozen storage. Tropical tilapia surimi gel quality was generally comparable to Alaskan Pollock and threadfin bream surimi gels but superior to other marine and freshwater fish surimi gels. The tropical freshwater specy, tilapia (*Oreochromis niloticus*) trends to be the potential or alternative surimi sources.

http://ora.kku.ac.th/RES_KKU/ATTACHMENTS_JOURNAL_PUBLICATION/3924.pdf

**Yamprayoona, J. & Noomhormb, A. (2000). Effects of preservation methods on geosmin content and off-flavor in Nile Tilapia (Oreochromis niloticus). *Journal of Aquatic Food Product Technology 9*(4): 95-107.**

In this study, the masking or reduction of off-flavor in tilapia due to various preservation methods such as salting, drying, frying, smoking, microwave heating, marinating and fermentation with carbohydrate mixture (som fak preparation) was investigated by subjecting the processed tilapia to sensory evaluation and analyzing the concentrations of geosmin (1,10-trans -dimethyl-trans -9-decaol) in the processed samples. Dry salting or brining muddy-flavored fish and then drying either by hot air at 50°C or sun-drying resulted to only a slight reduction in the geosmin content of the product. Deep-frying reduced the muddy flavor intensity and geosmin content in salted-dried tilapia. Pretreatment of tilapia fillets with acidified brine before smoking reduced geosmin content and masked the muddy flavor in the smoked product. Microwave cooking of fresh muddy-flavored tilapia showed no effect on its geosmin content nor its off-flavor. Marinating tilapia in acetic acid solution resulted in decreased muddy flavor, and longer marinating period led to lower geosmin content in the product. The geosmin content of som fak made from muddy-flavor and non-muddy-flavor tilapia differed significantly, although sensory evaluation yielded no significant differences between the two types of som fak, and the taste panelists preferred the product fermented for 3 days.



**Yamprayoon, J., & Noomhorm, A. (2003). Off-flavor in Nile Tilapia (Oreochromis niloticus). *OffFlavors in Aquaculture*, *848*, 235-245.**

Off-flavor causing agents in Nile Tilapia (Oreochromis niloticus) and various methods to mask this off-flavor are reviewed. Geosmin ($C_{12}H_{22}O$) and MIB (2-methylisoborneol) were reported as the major compounds that cause "muddy" or,'musty" flavor in fish. Relationships between sensory scores and instrumental results of geosmin analysis are discussed. Similar to other fish species, geosmin can be removed from Nile tilapia by keeping it in clean static water for 16 days. Effect of various treatments i.e., salting and drying, smoking, microwave heating, marinating and fermentation on off-flavor of tilapia is also described.

**Yanar, Y., Çelik, M., & Akamca, E. (2006). Effects of brine concentration on shelf-life of hot-smoked tilapia (Oreochromis niloticus) stored at 4°C. *Food Chemistry*, *97*(2), 244-247.**

This work evaluated the effect of brine concentration on the shelf-life of hot-smoked tilapia (*Oreochromis niloticus*) stored at 4 °C. The fish were brined in solutions of 5%, 10%, and 15% NaCl and unsalted fish were used as controls. The fish were then smoked, cooled and stored at 4 °C. Oxidative rancidity measured by the peroxide value (PV), and thiobarbituric acid number (TBA) showed increases with the storage time and also as a result of the increasing salt content in fish muscle. Hot smoked tilapia can be stored safely under refrigerated conditions for over 35 days, and 5% brine was found to be optimal for storage.