ENCAPSULATION OF Lactobacillus plantarum ISO14 FOR SYNBIOTIC TILAPIA FEED FORMULATION

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By

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

ENCAPSULATION OF *Lactobacilllus plantarum* ISO14 FOR SYNBIOTIC TILAPIA FEED FORMULATION

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Chairman : Shuhaimi Mustafa, PhD
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The increase cost of producing tilapia coupled with vigorous expansion of the industry pose a serious problem to the performance of the fish that lead to farmers loss. There is a need to develop feed additives incorporated in feed formulations to improve fish growth. The purpose of this study is to formulate a fish feed with synbiotic through encapsulation of *Lactobacillus plantarum* ISO14 with mannan to improve tilapia growth performance. The mannan was derived from palm kernel cake (PKC) and has the property of prebiotic. Since PKC are abundant and sustainable in Malaysia, its price is relatively low compared to imported ingredients and its supply for continuous fish feed production is promising. Encapsulation matrices optimization by response surface methodology (RSM) showed 1.66 % (w/v) of sodium alginate and 24.73 % (w/v) of mannan as coating materials would produce the highest survival of the probiotic. The verification experiment yielded a result close to the expected values, with no significant difference ($P > 0.05$) suggesting the model is adequate to be used as predictive model. The feed were formulated according to National Research Council (NRC) of standard tilapia nutritional requirement and added with encapsulated bacteria. Feeding trials in laboratory scale and industrial scale were conducted on growth performance of the tilapia. The fish were randomly assigned to two dietary treatments; control diet (without synbiotics) and synbiotic diet. Laboratory scale feeding demonstrated that synbiotic fed fish had a better growth rate with 12.6 ± 0.11 g fish^{-1} of weight gain compared to control fed fish 9.7 ± 0.04 g fish^{-1}. Feed conversion ratio (FCR) was also significantly lower in the synbiotic fed fish, 1.53 gg^{-1}, compared to the control fed fish1.85 gg^{-1} suggesting a higher growth performance in synbiotic fed fish. Similar results were observed in the industrial scale feeding with synbiotic fed fish showed a better feed efficiency ($P < 0.05$) with the FCR of 2.12 gg^{-1} compared to control fed fish 2.30 gg^{-1}. This study has contributes to a development of fish feed supplemented with synbiotics that able to increase tilapia growth performance in a sustainable way.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

ENKAPSULASI *Lactobacillus plantarum* ISO14 UNTUK PENCIPTAAN MAKANAN IKAN TILAPIA YANG DILENGKAPI SINBIOTIK

Oleh

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Peningkatan kos dalam menghasilkan tilapia ditambah dengan perkembangan pesat industri membawa masalah serius kepada tumbesaran ikan seterusnya menyebabkan kerugian kepada penternak. Terdapat keperluan untuk mencipta makanan tambahan yang dimasukkan dalam formulasi makanan bagi menambahbaik tumbesaran ikan. Tujuan kajian ini adalah untuk mencipta makanan ikan yang dilengkapi sinbiotik melalui enkapsulasi *Lactobacillus plantarum* ISO14 dengan mannan bagi meningkatkan prestasi ikan tilapia. Mannan diperolehi daripada kek isirung kelapa sawit (PKC) dan mempunyai sifat prebiotik. Memandangkan sumber PKC adalah banyak dan mampan di Malaysia, harganya adalah rendah berbanding bahan import dan bekalannya untuk pembangunan makanan ikan secara berterusan adalah menjanjikan. Pengoptimunan matriks enkapsulasi melalui metodologi permukaan tindak balas (RSM) menunjukkan 1.66 % (w/v) natrium alginate dan 24.73 % (w/v) mannan sebagai bahan salutan menghasilkan bilangan probiotik yang paling tinggi. Keputusan eksperimen pengesahan adalah hampir kepada nilai yang dijangka, dengan tiada perbezaan yang ketara ($P > 0.05$), menunjukkan model tersebut mencukupi untuk dijadikan sebagai model ramalan. Makanan ikan diformulasi berdasarkan nutrien asas keperluan tilapia Majlis Penyelidikan Kebangsaan (NRC) dan dicampur sinbiotik. Ujian haiwan pada skala makmal dan skala industri dijalankan ke atas tumbesaran ikan. Ikan dibahagikan secara rawak kepada dua kumpulan rawatan pemakanan; makanan kawalan (tanpa sinbiotik) dan makanan sinbiotik. Ujian haiwan skala makmal menunjukkan kumpulan sinbiotik mencatatkan prestasi pertumbuhan yang lebih bagus dengan 12.6 ± 0.11 g ikan^{-1} pertambahan berat berbanding kumpulan kawalan yang merekodkan 9.7 ± 0.04 g ikan^{-1}. Nisbah penukaran makanan (FCR) juga rendah secara ketara dalam kumpulan sinbiotik, 1.53 gg^{-1}, berbanding kumpulan kawalan 1.85 gg^{-1}, mencadangkan prestasi pertumbuhan yang lebih baik bagi kumpulan sinbiotik. Keputusan yang sama diperhatikan di ujian haiwan skala industri dengan kumpulan sinbiotik menunjukkan penyerapan nutrien yang lebih efisien ($P < 0.05$) pertumbuhan prestasi ikan kumpulan dengan sinbiotik lebih baik ($P < 0.05$) dengan FCR 2.12 gg^{-1} berbanding kumpulan kawalan 2.30 gg^{-1}. Kajian ini telah menyumbang kepada penciptaan makanan ikan yang dilengkapi sinbiotik yang mampu meningkatkan tumbesaran ikan tilapia dalam penternakan ikan yang mampan.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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AA	Amino acids
ANOVA	Analysis of variance
BD	Bulk density
BW	Body weight
CF	Crude fiber
CFU	Colony forming unit
Cm	Centimeter
CP	Crude protein
DOF	Department of Fisheries
ER	Expansion ratio
F	Floatability
FAO	Food and Agricultural Organization
FOS	Fructooligosaccharides
FI	Feed intake
FCR	Feed conversion ratio
G	Gram
h	Hour
IFFO	International Fishmeal and Fish Oil
HCl	Hydrochloric acid
HPLC	High performance liquid chromatography
L. plantarum	*Lactobacillus plantarum*
MJ/kg	Megajoules per kilogram
Mg	Milligram
Min	Minutes
Ml	Millilitre
mM	Millimolar
MOS	Mannanoligosaccharide
NRC	National Research Council
°C	Degree celcius
PKC	Palm kernel cake
pH	Hydrogen ion concentration
Rpm	Revolutions per minute
RSM	Response surface methodology
SEM	Standard error of mean
SSF	Solid state fermentation
µg	Microgram
µl	Microlitre

CHAPTER 1

INTRODUCTION

Aquaculture is a multibillion dollar industry that continues to grow in a rapid pace due to increasing human consumption demand for protein sources as the world population continue to rise. As per stated by Food and Agricultural Organization of United Nations (FAO) (2016), by 2050, the world population is foreseen to intensify to higher than nine billion people as compared to seven billion people presently. To cater this overpopulation, aquaculture, whereby equipped with high end technology is shown to be a prominent and emerging field to meet the increasing demands of fish as food, commercial products or rehabilitate endangered species. As a potential solution for the crisis, Tilapia is probably one of the most significant fish species to satisfy the demand due to their growing popularity among consumers. Tilapia is regarded as second most cultured fish in the world with global production of more than 4.5 million tons and is anticipated to escalate to 7.3 million tons by 2030 (FAO, 2014; Wang & Lu, 2016). The tilapia production increased over the past decade due to marketability, price stability and ease of aquaculture (Wang & Lu, 2016). However, increasing cost of producing tilapia coupled with vigorous expansion of the industry limitting its economic profitability, and the fish growth should be improved to help farmers to reduce costs and increase profits. According to Huynh *et al*. (2017), major expenditure of modern tilapia farm were mainly from the production of feed, covering about 66% to 84% of the total farming cost. This emphasizes the significance of using high quality feed with high protein components containing basic nutrients and also additional additives in which indirectly will keep the animal healthy and promote their growth (El- Haroun *et al*., 2006).

Usually, farmers utilized growth-promoting additives such as antibiotics to increase weight gain, reduce mortality and improve feed utilization (Shalaby *et al*., 2006). Yet, their inappropriate use can result in detrimental consequence to the animal and consumer (Defoirdt *et al*., 2011; Levy & Marshall, 2004). For instance, numbers of antibiotic resistance microorganisms have been detected in Malaysia such as multi-drug resistant *Salmonella* spp. found in tilapia (*Tilapia mossambica*) and catfish (*Clarias gariepinus*) acquired from ponds and wet markets in Malaysia (Budiati *et al*., 2013) and multidrug-resistant *Vibrio* spp. found in aquatic environments of west coast of Peninsular Malaysia (You *et al*., 2016). The development of antibiotic resistance in microorganisms due to improper use of antibiotics has led to an intensive research conducted on natural, alternative growth promoters such as probiotics, prebiotics and synbiotics to use in fish feeds (Abid *et al*., 2013; Ebrahimi *et al*., 2012; Gatesoupe, 1999; Irianto & Austin, 2002; Jahari *et al*., 2018; Mohanty *et al*., 1993; Verschuere *et al*., 2000).

Probiotic has been established for the first time in 1974 and is defined as 'organisms and substances that support intestinal microbial balance' (Parker, 1974). In an empirical way, probiotics composed of live microorganisms used as dietary additives in aquaculture and as a mean to promote health and growth of the host (Gatesoupe, 1999; Kesarcodi-Watson *et al*., 2008). On the other hand, Gibson and Roberfroid (1995) proposed the term prebiotic which defined as 'non-digestible food ingredients that selectively stimulating growth and/or activity of the microorganisms in the colon and give positive impact to the

host'. The synbiotics are combination of prebiotics and probiotics. Gibson and Roberfroid (1995) asserts the application of synbiotics concept may confer benefits of both pro- and prebiotics on fish growth largely because of the synergistic effect. The reason for their combined use is due to the prebiotic usefulness as substrate for fermentation to promote viability of the probiotic organisms, hence, would recompense host in a better manner (Collins & Gibson, 1999).

However, Biradar *et al*. (2005) has highlighted the condition for probiotic to be effective, the bacteria must possess some attributes such as resistance towards bile environment, gastrointestinal acidic, and easily reproduced. To address those challenges, bacteria must be encapsulated with protective substances as encapulation matrix. According to Sohail *et al*. (2011), encapsulation not only acting as a shelter against harsh condition, but also can increase the viability and stability of alive probiotic culture and make it easy to mass produce. Most of the prior studies uses alginate and prebiotic such as aloe-vera, psyllium, and fenugreek as a coating materials (Guo *et al*,, 2008; Haghshenas *et al.*, 2015; Lotfipour *et al*., 2012; Syahirah *et al*., 2013), however, in this study we uses prebiotic mannan-oligosaccharides (MOS) derived from palm kernel cake (PKC) as it is cheaper and its availability throughout the year are guaranteed (Sundu *et al*.,2006).

Currently, there are a lot of studies that were carried out in fish feed formulation to aid the tilapia production by manipulating the nutritional contents (El-Haroun, Goda, & Chowdhury, 2006; Essa *et al.,* 2010; Soltan & El-Laithy, 2008). However, the study regarding fish feed additive using synbiotic that has been produced from encapsulation of probiotic with prebiotic is still limited. Therefore, the general objective of the present study was to formulate a fish feed with synbiotic through encapsulation of probiotic *Lactobacillus plantarum* ISO14 with prebiotic mannan for improving tilapia growth performance. While, the specific objectives of this research were:

i. To encapsulates *L. plantarum* ISO14 using mannan and sodium alginate as coating materials for synbiotic feed formulation;

ii. To formulate synbiotic tilapia feed containing encapsulated bacteria;

iii. To investigate effects of feeding synbiotic tilapia feed on the growth performance and feed efficiency in red hybrid tilapia.

REFERENCES

Aas, T. S., Oehme, M., Sørensen, M., He, G., Lygren, I., & Åsgård, T. (2011). Analysis of pellet degradation of extruded high energy fish feeds with different physical qualities in a pneumatic feeding system. *Aquacultural Engineering*, *44*(1), 25–34.

Abid, A., Davies, S. J., Waines, P., Emery, M., Castex, M., Gioacchini, G., … Merrifield, D. L. (2013). Dietary synbiotic application modulates Atlantic salmon (*Salmo salar*) intestinal microbial communities and intestinal immunity. *Fish & Shellfish Immunology*, *35*(6), 1948–1956.

Adeoye, A. (2016). The effects of selected bio-active feed additives on NIle tilapia (*Oreochromis niloticus*) production and health (Doctoral dissertation, University of Plymouth).

Agbo, N. W. (2008). Oilseed meals as dietary protein sources for juvenile Nile tilapia (*Oreochromis niloticus* L.). *PhD Thesis*. Institute of Aquaculture, University of Stirling, Scotland, UK.

Agung, L. A., & Yuhana, M. (2015). Application of micro-encapsulated probiotic *Bacillus* NP5 and prebiotic mannan oligosaccharide (MOS) to prevent streptococcosis on tilapia *Oreochromis niloticus*. *Research Journal of Microbiology*, *10*(12), 571.

Ai, Q., Xu, H., Mai, K., Xu, W., Wang, J., & Zhang, W. (2011). Effects of dietary supplementation of *Bacillus subtilis* and fructooligosaccharide on growth performance, survival, non-specific immune response and disease resistance of juvenile large yellow croaker, *Larimichthys crocea*. *Aquaculture*, *317*(1–4), 155–161.

Akhter, N., Wu, B., Memon, A. M., & Mohsin, M. (2015). Probiotics and prebiotics associated with aquaculture: A review. *Fish & Shellfish Immunology*, *45*(2), 733–741.

Akter, M. N., Sutriana, A., Talpur, A. D., & Hashim, R. (2016). Dietary supplementation with mannan oligosaccharide influences growth, digestive enzymes, gut morphology, and microbiota in juvenile striped catfish, *Pangasianodon hypophthalmus*. *Aquaculture International*, *24*(1), 127–144.

Alceste-Oliviero, C., & Martínez-Espinoza, M. (2000, February). Regional review of aquaculture status and development trends in the Latin America and Caribbean. In *Book of Synopses. NACA and FAO International Conference on Aquaculture in the Third Millenium* (pp. 20-25).

Al-Dohail, M. A., Hashim, R., & Aliyu-Paiko, M. (2009). Anaerobic bacteria isolated from Oscars (*Astronotus ocellatus*), angel animals: a review. *Critical Reviews in Food Science & Nutrition*, *43*, 19–60.

Allaman, I. B., Reis Neto, R. V., Freitas, R. T. F. de, Freato, T. A., Lago, A. de A., Costa, A. C., & Lima, R. R. de. (2013). Weight and morphometric growth of different strains of tilapia (*Oreochromis* sp). *Brazilian Journal of Animal Science*, *42*(5), 305–311.

Aly, S. M. (2009). Probiotics and aquaculture. *CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition & Natural Resources*, *403*, 1–16.

Aly, S. M., Mohamed, M. F., & John, G. (2008). Effect of probiotics on the survival, growth and challenge infection in Tilapia nilotica (*Oreochromis niloticus*). *Aquaculture Research*, *39*(6), 647–656.

Amlashi, A. S., Falahatkar, B., Sattari, M., & Gilani, M. T. (2011). Effect of dietary vitamin E on growth, muscle composition, hematological and immunological parameters of sub-yearling beluga *Huso huso* L. *Fish & Shellfish Immunology*, *30*(3), 807–814.

Anal, Anil K., Bhopatkar, D., Tokura, S., Tamura, H., & Stevens, W. F. (2003). Chitosan-alginate multilayer beads for gastric passage and controlled intestinal release of protein. *Drug Development & Industrial Pharmacy*, *29*(6), 713–724.

Anal, Anil K., & Stevens, W. F. (2005). Chitosan–alginate multilayer beads for controlled release of ampicillin. *International Journal of Pharmaceutics*, *290*(1–2), 45–54.

Anal, Anil Kumar, & Singh, H. (2007). Recent advances in microencapsulation of probiotics for industrial applications and targeted delivery. *Trends in Food Science & Technology*, *18*(5), 240–251.

Anon. (1984). Introducing the tilapias. ICLARM Newsletter. January 1984. 7(1):3

Aspinall, G. O. (1970). Polysaccharides ([1st ed.]). Oxford, [England] ; Elmsford, New York : Pergamon Press. Retrieved from https://trove.nla.gov.au/work/7317966

Atanda, A. N. (2012). Fish species diversification in Agriculture for the success of the agriculture transformation agenda: The role of tilapia production. *2012 FISON Annual Public Lecture. 21pp*.

Azevedo, R. V. de, Filho, F., Carlos, J., Pereira, S. L., Cardoso, L. D., Andrade, D. R. de,. … Vazquez, M. (2016). Dietary mannan oligosaccharide and *Bacillus subtilis* in diets for Nile tilapia (*Oreochromis niloticus*). *Animal Sciences*, *38*(4), 347–353.

Azevedo, R. V. de, Fosse Filho, J. C., Cardoso, L. D., Mattos, D. da C., Júnior, V., Vazquez, M., & Andrade, D. R. de. (2015). Economic evaluation of prebiotics, probiotics and synbiotics in juvenile Nile tilapia. *Agronomy & Crop Science*, *46*(1), 72–79.

Azevedo, P. A., Cho, C. Y., Leeson, S., & Bureau, D. P. (1998). Effects of feeding level and water temperature on growth, nutrient and energy utilization and waste

outputs of rainbow trout (*Oncorhynchus mykiss*). *Aquatic Living Resources*, *11*(4), 227–238.

Bernama (2016, Jun 27), Dept sets high target for tilapia production - The Star. Retrieved from https://www.thestar.com.my/metro/community/2016/06/27/dept-sets-high-target-for-tilapia-production/

Bello, B., Mustafa, S., Tan, J. S., Ibrahim, T. A. T., Tam, Y. J., Ariff, A. B., ... & Abbasiliasi, S. (2018). Evaluation of the effect of soluble polysaccharides of palm kernel cake as a potential prebiotic on the growth of probiotics. *3 Biotech*, *8*(8), 346.

Bhosale, S. V., Bhilave, M. P., & Nadaf, S. B. (2010). Formulation of fish feed using ingredients from plant sources. *Research Journal Agricultural Science*, *1*(3), 284–287.

Bielecka, M., Biedrzycka, E., & Majkowska, A. (2002). Selection of probiotics and prebiotics for synbiotics and confirmation of their in vivo effectiveness. *Food Research International*, *35*(2–3), 125–131.

Biradar, S. S., Bahagvati, S. T., & Shegunshi, B. (2005). Probiotics and antibiotics: a brief overview. *The Internet Journal of Nutrition & Wellness*, *2*(1), 1–6.

Bomba, A., Nemcova, R., Gancarcikova, S., Herich, R., Guba, P., & Mudronova, D. (2002). Improvement of the probiotic effect of micro-organisms by their combination with maltodextrins, fructo oligosaccharides and polyunsaturated fatty acids. *British Journal of Nutrition*, *88*(S1), S95–S99.

Boonanuntanasarn, S., Wongsasak, U., Pitaksong, T., & Chaijamrus, S. (2016). Effects of dietary supplementation with β-glucan and synbiotics on growth, haemolymph chemistry, and intestinal microbiota and morphology in the P acific white shrimp. *Aquaculture Nutrition*, *22*(4), 837–845.

Bostock, J., McAndrew, B., Richards, R., Jauncey, K., Telfer, T., Lorenzen, K., & Gatward, I. (2010). Aquaculture: global status and trends. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, *365*(1554), 2897–2912.

Budiati, T., Rusul, G., Wan-Abdullah, W. N., Arip, Y. M., Ahmad, R., & Thong, K. L. (2013). Prevalence, antibiotic resistance and plasmid profiling of *Salmonella* in catfish (*Clarias gariepinus*) and tilapia (*Tilapia mossambica*) obtained from wet markets and ponds in Malaysia. *Aquaculture*, *372*, 127–132.

Caipang, C. M. A., & Lazado, C. C. (2015). Nutritional impacts on fish mucosa: immunostimulants, pre- and probiotics. *Mucosal Health in Aquaculture* (pp. 211–272). San Diego: Academic Press.

Căpriţă, R., Căpriţă, A., & Julean, C. (2010). Biochemical aspects of non-starch polysaccharides. *Scientific Papers Animal Science & Biotechnologies*, *43*(1), 368–374.

Carnevali, O., Sun, Y.-Z., Merrifield, D. L., Zhou, Z., & Picchietti, S. (2014). Probiotic Applications in Temperate and Warm Water Fish Species. In *Aquaculture Nutrition* (pp. 253–289). Wiley-Blackwell.

Carnevali, O., Zamponi, M. C., Sulpizio, R., Rollo, A., Nardi, M., Orpianesi, C., … Cresci, A. (2004). Administration of probiotic strain to improve sea bream wellness during development. *Aquaculture International*, *12*(4–5), 377–386.

Champagne, C. P., Gaudy, C., Poncelet, D., & Neufeld, R. J. (1992). *Lactococcus lactis* release from calcium alginate beads. *Applied & Environmental Microbiology*, *58*(5), 1429–1434.

Chandramouli, V., Kailasapathy, K., Peiris, P., & Jones, M. (2004). An improved method of microencapsulation and its evaluation to protect *Lactobacillus* spp. in simulated gastric conditions. *Journal of Microbiological Methods*, *56*(1), 27–35.

Chapman, F. A. (2000). Culture of hybrid tilapia: A reference profile. University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS.

Chen, K.-N., Chen, M.-J., & Lin, C.-W. (2006). Optimal combination of the encapsulating materials for probiotic microcapsules and its experimental verification (R1). *Journal of Food Engineering*, *76*(3), 313–320.

Chen, K.-N., Chen, M.-J., Liu, J.-R., Lin, C.-W., & Chiu, H.-Y. (2005). Optimization of incorporated prebiotics as coating materials for probiotic microencapsulation. *Journal of Food Science*, *70*(5), M260–M266.

Collins, M. D., & Gibson, G. R. (1999). Probiotics, prebiotics, and synbiotics: approaches for modulating the microbial ecology of the gut. *The American Journal of Clinical Nutrition*, *69*(5), 1052s–1057s.

Conway, H. F., & Anderson, R. A. (1973). Protein-fortified extruded food products. *Cereal Science Today, 18(4),* 94.

Cuskin, F., Lowe, E. C., Temple, M. J., Zhu, Y., Cameron, E. A., Pudlo, N. A., … Cartmell, A. (2015). Human gut *Bacteroidetes* can utilize yeast mannan through a selfish mechanism. *Nature*, *517*(7533), 165.

Daniel, N. (2018). A review on replacing fish meal in aqua feeds using plant protein sources. *International Journal of Fisheries & Aquatic Studies, 6*(2), 164-179

Daud, M. J., & Jarvis, M. C. (1992). Mannan of oil palm kernel. *Phytochemistry*, *31*(2), 463–464.

Dauda, A. B., Folorunso, L. A., & Dasuki, A. (2013). Use of probiotics for sustainable aquaculture production in Nigeria. *Journal of Agriculture & Social Research (JASR)*, *13*(2), 42–52.

De Cruz, C. R., Kamarudin, M. S., Saad, C. R., & Ramezani-Fard, E. (2015). Effects of extruder die temperature on the physical properties of extruded fish pellets containing taro and broken rice starch. *Animal Feed Science & Technology*, *199*, 137–145.

Defoirdt, T., Sorgeloos, P., & Bossier, P. (2011). Alternatives to antibiotics for the control of bacterial disease in aquaculture. *Current Opinion in Microbiology*, *14*(3), 251–258.

Delgado, G. T. C., Tamashiro, W. M. da S. C., Junior, M. R. M., Moreno, Y. M. F., & Pastore, G. M. (2011). The putative effects of prebiotics as immunomodulatory agents. *Food Research International*, *44*(10), 3167–3173.

De Silva, S. S. (1995). Supplementary feeding in semi-intensive aquaculture systems. *FAO Fisheries Technical Paper*, 24-60.

De Silva, S. S., & Anderson, T. A. (1995). Fish Nutrition in Aquaculture. Chapman and Hall, London, pp 319.

Dimitroglou, A., Reynolds, P., Ravnoy, B., Johnsen, F., Sweetman, J. W., Johansen, J., & Davies, S. J. (2011). The effect of Mannan Oligosaccharide supplementation on Atlantic salmon smolts (*Salmo salar* L.) fed diets with high levels of plant proteins. *Journal of Aquaculture Research & Devevelopment*, *1*, 011.

Dimitroglou, A., Merrifield, D. L., Carnevali, O., Picchietti, S., Avella, M., Daniels, C., … Davies, S. J. (2011). Microbial manipulations to improve fish health and production–a Mediterranean perspective. *Fish & Shellfish Immunology*, *30*(1), 1–16.

Dimitroglou, Arkadios, Merrifield, D. L., Spring, P., Sweetman, J., Moate, R., & Davies, S. J. (2010). Effects of mannan oligosaccharide (MOS) supplementation on growth performance, feed utilisation, intestinal histology and gut microbiota of gilthead sea bream (*Sparus aurata*). *Aquaculture*, *300*(1–4), 182–188.

Ding, X., Li, Z., Chen, Y., Lin, H., Yang, Y., & Yang, K. (2004). Effects of probiotics on growth and activities of digestive enzymes of *Pennaus vannamei*. *Journal of fishery sciences of China*, *11*(6), 580–584.

DOF (2016), Annual Fisheries Statistics 2015. Department of Fisheries, Malaysia, Ministry of Agriculture & Agro-based Industries, Putrajaya

Dusterhoft, E. M., Posthumus, M. A., & Voragen, A. G. J. (1992). Non-starch polysaccharides from sunflower (*Helianthus annuus*) meal and palm-kernel (*Elaeis guineensis*) meal–investigation of the structure of major polysaccharides. *Journal of the Science of Food & Agriculture*.

Ebrahimi, G. H., Ouraji, H., Khalesi, M. K., Sudagar, M., Barari, A., Zarei Dangesaraki, M., & Jani Khalili, K. H. (2012). Effects of a prebiotic, Immunogen®, on feed utilization, body composition, immunity and resistance to *Aeromonas*

hydrophila infection in the common carp *Cyprinus carpio* (Linnaeus) fingerlings. *Journal of Animal Physiology & Animal Nutrition*, *96*(4), 591–599.

Eknath, A. E., & Hulata, G. (2009). Use and exchange of genetic resources of Nile tilapia (*Oreochromis niloticus*). *Reviews in Aquaculture*, *1*(3–4), 197–213.

El- Haroun, E. R., Goda, A. M. a.-S., & Chowdhury, M. A. K. (2006). Effect of dietary probiotic Biogen® supplementation as a growth promoter on growth performance and feed utilization of Nile tilapia *Oreochromis niloticus* (L.). *Aquaculture Research*, *37*(14), 1473–1480.

El-Sayed, A.M., & Teshima, S. (1991). Tilapia nutrition in aquaculture. *Reviews in Aquatic*
Sciences. 5(3-4): pp. 247-265.

El-Sayed, A. M. (1999). Alternative dietary protein sources for farmed tilapia, *Oreochromis* spp. *Aquaculture*, *179*(1–4), 149–168.

El-Sayed, A. M., Mansour, C. R., & Ezzat, A. A. (2003). Effects of dietary protein levels on spawning performance of Nile tilapia (*Oreochromis niloticus*) brood stock reared at different water salinities. *Aquaculture. 220*: pp. 619-632.

El-Sayed, A. M. (2006). *Tilapia culture*. Retrieved from https://books.google.com.my/books?hl=en&lr=&id=hgiLjY6Cx_0C&oi=fnd&pg=PR5&dq=tilapia+culture&ots=4sAyERIi_d&sig=XFjuIFeqGdY2ZC8ULlVAhBnpQrg&redir_esc=y#v=onepage&q=tilapia%20culture&f=false

El-Sayed, A. M. (2006). Tilapia Culture. CABI Publishing, Oxfordshire. pp. 277.

El-Sayed, A. M. (2008). Tilapia feed and feeding in semi-intensive culture systems. In *8th International Symposium on Tilapia in Aquaculture (ISTA8) Cairo, Egypt* (pp. 717–723).

El-Shafei, K., Sharaf, M., Ibrahim, A., Sadek, I., & El-Sayed, S. (2013). Evaluation of *Lactobacillus plantarum* as a probiotic in aquaculture: emphasis on growth performance and innate immunity. *Journal of Applied Sciences Research*, *9*(1), 572-582.

Englyst, H. N., Quigley, M. E., & Hudson, G. J. (1994). Determination of dietary fibre as non-starch polysaccharides with gas–liquid chromatographic, high-performance liquid chromatographic or spectrophotometric measurement of constituent sugars. *Analyst*, *119*(7), 1497–1509.

Essa, M. A., El-Serafy, S. S., El-Ezabi, M. M., Daboor, S. M., Esmael, N. A., & Lall, S. P. (2010). Effect of different dietary probiotics on growth, feed utilization and digestive enzymes activities of Nile tilapia, *Oreochromis niloticus*. *Journal of the Arabian Aquaculture Society*, *5*(2), 143–162.

FAO (2002). Fishery Statistics. Aquaculture production. Food & Agricultural Organization of United Nations, 90(2).

FAO (2011). FISHSTAT plus: Universal Software for Fishery Statistical Time Series, Version 2.3. FAO Fisheries Department, Fishery Information, Data and Statistical Unit, Food & Agricultural Organization of United Nations, Rome.

FAO (2014). The State of World Fisheries and Aquaculture 2014 (SOFIA). Opportunities and challenges. Fisheries & Aquaculture Department, Food & Agriculture Organization of United Nations, Rome pp: 1–243.

FAO (2016), The State of World Fisheries and Aquaculture-Contributing to food security and nutrition for all. Fisheries & Aquaculture Department, Food & Agriculture Organization of United Nations, Rome pp: 200.

Ferreira, S. C., Bruns, R. E., Ferreira, H. S., Matos, G. D., David, J. M., Brandao, G. C., … Souza, A. S. (2007). Box-Behnken design: an alternative for the optimization of analytical methods. *Analytical Chemistry*, *597*(2), 179–186.

Fooks, L. J., Fuller, R., & Gibson, G.R. (1999). Prebiotics, probiotics and human gut microbiology. International Dairy Journal, 9:53–61

Firouzbakhsh, F., Mehrabi, Z., Heydari, M., Khalesi, M. K., & Tajick, M. A. (2014). Protective effects of a synbiotic against experimental *Saprolegnia parasitica* infection in rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Research*, *45*(4), 609–618.

Galindo, A. B. (2004). *Lactobacillus plantarum* 44A *a*s a live feed supplement for freshwater fish.*PhD Thesis*. Wageningen University, Wageninge, Netherlands.

Gatesoupe, F. J. (1999). The use of probiotics in aquaculture. *Aquaculture*, *180*(1), 147–165.

Gatesoupe, F.-J. (2008). Updating the importance of lactic acid bacteria in fish farming: natural occurrence and probiotic treatments. *Journal of Molecular Microbiology & Biotechnology*, *14*(1–3), 107–114.

Gemeiner, P., Švec, F., & Norrlöw, O. (1994). Natural and synthetic carriers suitable for immobilization of viable cells, active organelles, and molecules. In *Immobilized biosystems* (pp. 1–128). Springer.

Geng, X., Dong, X.-H., Tan, B.-P., Yang, Q.-H., Chi, S.-Y., Liu, H.-Y., & Liu, X.-Q. (2012). Effects of dietary probiotic on the growth performance, non-specific immunity and disease resistance of cobia, *Rachycentron canadum*. *Aquaculture Nutrition*, *18*(1), 46–55.

Gibson, G. R., Saavedra, J. M., MacFarlane, S., & MacFarlane, G. T. (1997). Probiotics and intestinal infections. In *Probiotics 2* (pp. 10–39). Springer.

Gibson, Glenn R., & Roberfroid, M. B. (1995). Dietary modulation of the human colonic microbiota: introducing the concept of prebiotics. *The Journal of Nutrition*, *125*(6), 1401–1412.

Glencross, B., Rutherford, N., & Jones, B. (2011). Evaluating options for fishmeal replacement in diets for juvenile barramundi (*Lates calcarifer*). *Aquaculture Nutrition*, *17*(3), e722–e732.

Goh, Y. J., & Klaenhammer, T. R. (2015). Genetic mechanisms of prebiotic oligosaccharide metabolism in probiotic microbes. *Annual Review of Food Science & Technology*, *6*, 137–156.

Gram, L., & Ringø, E. (2005). Prospects of fish probiotics. In *Biology of Growing Animals* (Vol. 2, pp. 379–417). Elsevier.

Guo, Q., Cui, S. W., Wang, Q., & Christopher Young, J. (2008). Fractionation and physicochemical characterization of psyllium gum. *Carbohydrate Polymers*, *73*(1), 35–43.

Gunasekera, R. M., Shim, K. F., & Lam, T. J. (1996). Influence of protein content of broodstock diets on larval quality and performance in Nile tilapia, *Oreochomis niloticus* (L.). *Aquaculture 146*: pp. 245-259.

Gupta, M. V., & Acosta, B. O. (2004). A review of global tilapia farming practices. *Aquaculture Asia*, *9*, 7-12.

Güroy, B., Şahin, İ., Kayalı, S., Mantoğlu, S., Canan, B., Merrifield, D. L., … Güroy, D. (2013). Evaluation of feed utilization and growth performance of juvenile striped catfish *Pangasianodon hypophthalmus* fed diets with varying inclusion levels of corn gluten meal. *Aquaculture Nutrition*, *19*(3), 258–266.

Gurry, T. (2017). Synbiotic approaches to human health and well-being. *Microbial Biotechnology*, *10*(5), 1070–1073.

Guzmán-Villanueva, L. T., Tovar-Ramírez, D., Gisbert, E., Cordero, H., Guardiola, F. A., Cuesta, A., … Esteban, M. A. (2014). Dietary administration of β-1, 3/1, 6-glucan and probiotic strain *Shewanella putrefaciens*, single or combined, on gilthead seabream growth, immune responses and gene expression. *Fish & Shellfish Immunology*, *39*(1), 34–41.

Haghighi, D, T., M, Kapour, F. C., & Tabar, S. A. E. (2010). The Effect Of Different Levels Of Biomin Imbo Synbiotic On Growth And, Survival Of Rutilus Frisii Kutum Fry. *Journal of Fisheries*, *4*(315), 1–14.

Haghshenas, B., Abdullah, N., Nami, Y., Radiah, D., Rosli, R., & Khosroushahi, A. Y. (2015). Microencapsulation of probiotic bacteria *Lactobacillus plantarum 15HN* using alginate-psyllium-fenugreek polymeric blends. *Journal of Applied Microbiology*, *118*(4), 1048.

Harikrishnan, R., Balasundaram, C., & Heo, M.-S. (2010). *Lactobacillus sakei* BK19 enriched diet enhances the immunity status and disease resistance to *streptococcosis* infection in kelp grouper, *Epinephelus bruneus*. *Fish & Shellfish Immunology*, *29*(6), 1037–1043.

Hashim, R., Chong, A. S., Fatan, N. A., Layman, N., & Ali, A. (2002). Production of hybrid red tilapia, *Oreochromis mossambicus* x *O. niloticus*, at varying stocking densities in portable canvas tanks. *Journal of Applied Aquaculture*, *12*(3), 1–12.

Hassaan, M. S., Soltan, M. A., Agouz, H. M., & Badr, A. M. (2013). Influences of calcium/phosphorus ratio on supplemental microbial phytase efficiency for Nile tilapia (*Oreochromis niloticus*). *The Egyptian Journal of Aquatic Research*, *39*(3), 205–213.

Hegenbart, S. (1993). Encapsulated ingredients keep problems covered. *Journal of Food Products Marketing*, 29–50.

Higgs, D. A., Dosanjh, B. S., Prendergast, A. F., Beams, R. M., Hardy, R. W., Riley, W., & Deacon, G. (1995). Nutrition and Utilization Technology in Aquaculture. *Champaign II*. *Chapman and Hall Company*, New York, USA.

Hoshino, T., Ishizaki, K., Sakamoto, T., Kumeta, H., Yumoto, I., Matsuyama, H., & Ohgiya, S. (1997). Isolation of a *Pseudomonas* species from fish intestine that produces a protease active at low temperature. *Letters in Applied Microbiology*, *25*(1), 70–72.

Hu, C. J., Chen, S. M., Pan, C., & Huang, C. (2006). Effects of dietary vitamin A or b-carotene on growth of juvenile hybrid tilapia, *Oreochromis niloticus x O. Aureus*, *Aquaculture. 253*: pp. 602-607.

Huynh, T.-G., Shiu, Y.-L., Nguyen, T.-P., Truong, Q.-P., Chen, J.-C., & Liu, C.-H. (2017). Current applications, selection, and possible mechanisms of actions of synbiotics in improving the growth and health status in aquaculture: A review. *Fish & Shellfish Immunology*, *64*, 367–382.

IFFO 2013. Present supply status of fish meal and fish oil. *Global Aquaculture Advocate*.

Irianto, A., & Austin, B. (2002). Probiotics in aquaculture. *Journal of Fish Diseases*, *25*(11), 633–642.

Irianto, A., & Austin, B. (2002). Use of probiotics to control furunculosis in rainbow trout, *Oncorhynchus mykiss* (Walbaum). *Journal of fish diseases*, *25*(6), 333-342.

Iwana, H., Masuda, H., Fujisawa, T., Suzuki, H., & Mitsuoka, T. (1993). Isolation and identification of *Bifidobacterium* spp. in commercial yogurts sold in Europe. *Bifidobacteria & Microflora*, *12*(1), 39–45.

Jahari, M. A., Mustafa, S., Roslan, M. A. H., Manap, Y. A., Lamasudin, D. U., & Jamaludin, F. I. (2018). The Effects of Synbiotics and Probiotics Supplementation on Growth Performance of Red Hybrid Tilapia, *Oreochromis mossambicus* x *Oreochromis niloticus*. *Journal of Biochemistry, Microbiology & Biotechnology*, *6*(1), 5–9.

Jahromi, M. F., Liang, J. B., Abdullah, N., Goh, Y. M., Ebrahimi, R., & Shokryazdan, P. (2015). Extraction and characterization of oligosaccharides from palm kernel cake as prebiotic. *BioResources*, *11*(1), 674–695.

Jarimopas, P., & Veerasidth, P. (1986). Realized response Thai Red Tilapia to weight-specific selection for growth. *Food & Agriculture Organization of the United Nations (FAO)*.

Jaskari, J., Kontula, P., Siitonen, A., Jousimies-Somer, H., Mattila-Sandholm, T., & Poutanen, K. (1998). Oat β-glucan and xylan hydrolysates as selective substrates for *Bifidobacterium* and *Lactobacillus* strains. *Applied Microbiology & Biotechnology*, *49*(2), 175–181.

Jauncey, K., & Ross, B. (1982). A guide to tilapia feeds and feeding (No. 639.31 J41g). Scotland, GB: Institute of Aquaculture.

Jatobá, A., do Nascimento Vieira, F., Buglione-Neto, C. C., Mourino, J. L. P., Silva, B. C., Seiftter, W. Q., & Andreatta, E. R. (2011). Diet supplemented with probiotic for Nile tilapia in polyculture system with marine shrimp. *Fish Physiology & Biochemistry*, *37*(4), 725–732.

John, B. P. (2014). Supplementing soybean meal with Camelina (*Camelina sativa*) in tilapia diets and optimizing commercial tilapia diets for use in intensive systems in the Western Region of the United States (Doctoral Dissertation, University of Arizona).

Kalidas, N. R., Saminathan, M., Ismail, I. S., Abas, F., Maity, P., Islam, S. S., … Shaari, K. (2017). Structural characterization and evaluation of prebiotic activity of oil palm kernel cake mannanoligosaccharides. *Food Chemistry*, *234*, 348–355.

Karapanagiotidis, I. T., Bell, M. V., Little, D. C., Yakupitiyage, A., & Rakshit, S. K. (2006).
Polyunsaturated fatty acid content of wild and farmed Tilapias in Thailand: effect of
aquaculture practices and implications for human nutrition. *Journal of Agricultural & Food Chemistry 54:* pp. 4304– 310.

Kechik, I. bin A. (1995). Aquaculture in Malaysia (pp. 125–135). Presented at the Towards sustainable aquaculture in Southeast Asia & Japan: Proceedings of the Seminar-Workshop on Aquaculture Development in Southeast Asia, Iloilo City, Philippines, 26-28 July, 1994, SEAFDEC Aquaculture Department. Retrieved from http://repository.seafdec.org.ph/handle/10862/113

Keong, N. W. (2004). Researching the use of palm kernel cake in aquaculture feeds. *Malaysian Palm Oil Board*, *19*.

Kesarcodi-Watson, A., Kaspar, H., Lategan, M. J., & Gibson, L. (2008). Probiotics in aquaculture: the need, principles and mechanisms of action and screening processes. *Aquaculture*, *274*(1), 1–14.

Khater, E. S. G., Bahnasawy, A. H., & Ali, S. A. (2014). Physical and mechanical properties of fish feed pellets. *Journal of Food Processing & Technology*, *5*(10), 1.

Kiron, V. (2012). Fish immune system and its nutritional modulation for preventive health care. *Animal Feed Science & Technology*, *173*(1–2), 111–133.

Knudsen, K. E. B. (1997). Carbohydrate and lignin contents of plant materials used in animal feeding. *Animal Feed Science & Technology*, *67*(4), 319–338.

Kocher, A. (2004). The potential for immunosaccharides to maximize growth performance. *Interfacing Immunity, Gut Health & Performance*, 107–116.

Kolida, S., & Gibson, G. R. (2011). Synbiotics in health and disease. *Annual Review of Food Science & Technology*, *2*, 373–393.

Krasaekoopt, W., Bhandari, B., & Deeth, H. (2003). Evaluation of encapsulation techniques of probiotics for yoghurt. *International Dairy Journal*, *13*(1), 3–13.

Krasaekoopt, W., Bhandari, B., & Deeth, H. (2004). The influence of coating materials on some properties of alginate beads and survivability of microencapsulated probiotic bacteria. *International Dairy Journal*, *14*(8), 737–743.

Lacroix, C., Paquin, C., & Arnaud, J.-P. (1990). Batch fermentation with entrapped growing cells of *Lactobacillus casei*. *Applied Microbiology & Biotechnology*, *32*(4), 403–408.

Lash, B. W., Mysliwiec, T. H., & Gourama, H. (2005). Detection and partial characterization of a broad-range bacteriocin produced by *Lactobacillus plantarum* (ATCC 8014). *Food Microbiology*, *22*(2), 199–204.

Lauzon, H. L., Pérez- Sánchez, T., Merrifield, D. L., Ringø, E., & Balcázar, J. L. (2014). Probiotic Applications in Cold Water Fish Species. In *Aquaculture Nutrition* (pp. 223–252). Wiley-Blackwell.

Levy, S. B., & Marshall, B. (2004). Antibacterial resistance worldwide: causes, challenges and responses. *Nature Medicine*, *10*(12s), S122.

Li, P., & Gatlin III, D. M. (2004). Dietary brewers yeast and the prebiotic Grobiotic™ AE influence growth performance, immune responses and resistance of hybrid striped bass (*Morone chrysops* x *M. saxatilis*) to *Streptococcus iniae* infection. *Aquaculture*, *231*(1–4), 445–456.

Lim, C. E., & Webster, C. D. (2006). Nutrient requirements. *Tilapia: Biology, Culture and Nutrition. Food Products Press, New York, USA*, 469-501.

Lim, C., Yildirim-Aksoy, M., & Klesius, P. (2011). Lipid and fatty acid requirements of tilapias. *North American Journal of Aquaculture*, *73*(2), 188-193.

Liong, P. C., Hanafi, H. B., Merican, Z. O., & Nagaraj, G. (1988). Aquaculture development in Malaysia (pp. 73–90). Presented at the Seminar on Aquaculture Development in Southeast Asia, 8-12 September 1987, Iloilo City, Philippines, SEAFDEC Aquaculture Department. Retrieved from http://repository.seafdec.org.ph/handle/10862/140

Lotfipour, F., Mirzaeei, S., & Maghsoodi, M. (2012). Preparation and characterization of alginate and psyllium beads containing *Lactobacillus acidophilus*. *The Scientific World Journal*, *2012*.

Lovell, T. (1989). Nutrition and feeding of fish (Vol. 260). New York: Van Nostrand Reinhold.

Mair, G. C. (2002, February). Tilapia genetics and breeding in Asia. In *Tilapia Farming in the 21st Century, Proceedings of the International Forum on Tilapia Farming in the 21st Century*.

Mazlum, Y., Yılmaz, E., Genç, M. A., & Guner, O. (2011). A preliminary study on the use of mannan oligosaccharides (MOS) in freshwater crayfish, *Astacus leptodactylus Eschscholtz*, 1823 juvenile diets. *Aquaculture International*, *19*(1), 111–119.

Mehrabi, Z., Firouzbakhsh, F., & Jafarpour, A. (2012). Effects of dietary supplementation of synbiotic on growth performance, serum biochemical parameters and carcass composition in rainbow trout (*Oncorhynchus mykiss*) fingerlings. *Journal of Animal Physiology & Animal Nutrition*, *96*(3), 474–481.

Merrifield, D. L., Dimitroglou, A., Foey, A., Davies, S. J., Baker, R. T., Bøgwald, J., … Ringø, E. (2010). The current status and future focus of probiotic and prebiotic applications for salmonids. *Aquaculture*, *302*(1–2), 1–18.

Mohanty, S. N., Swain, S. K., & Tripathi, S. D. (1993). Growth and survival of rohu spawn fed on a liver based diet. *Journal of the Inland Fisheries Society of India*, *25*, 41–44.

Monaghan, R. L., Gagliardi, M. M., & Streicher, S. L. (1999). Culture preservation and inoculum development. *Manual of Industrial Microbiology & Biotechnology*, 29–48.

Nayak, S. K. (2010). Probiotics and immunity: a fish perspective. *Fish & Shellfish Immunology*, *29*(1), 2–14.

Nekoubin, H., Gharedaashi, E., Imanpour, M. R., Nowferesti, H., & Asgharimoghadam, A. (2012). The influence of synbiotic (Biomin Imbo) on growth factors and survival rate of Zebrafish (*Danio rerio*) larvae via supplementation with biomarker. *Drugs*, *10*, 13.

Newaj-Fyzul, A., Al-Harbi, A. H., & Austin, B. (2014). Developments in the use of probiotics for disease control in aquaculture. *Aquaculture*, *431*, 1–11.

Ng, W. K., & Chong, C. Y. (2004). An overview of lipid nutrition with emphasis on alternative lipid sources in tilapia feeds. *At: ag. arizona. edu/azaqua/ista/ista6/6abstracts/Ng/Ng_lipids. doc*.

Ng, W.-K., & Romano, N. (2013). A review of the nutrition and feeding management of farmed tilapia throughout the culture cycle. *Reviews in Aquaculture*, *5*(4), 220–254.

Ngamkala, S., Futami, K., Endo, M., Maita, M., & Katagiri, T. (2010). Immunological effects of glucan and *Lactobacillus rhamnosus* GG, a probiotic bacterium, on Nile tilapia *Oreochromis niloticus* intestine with oral *Aeromonas* challenges. *Fisheries Science*, *76*(5), 833–840.

Nguyen, T. N. (2008). The utilization of soybean products in tilapia feed-A review. In *Proceedings of the 8th International Symposium on Tilapia in Aquaculture. The Central Laboratory for Aquaculture Research, Cairo* (pp. 53–65).

Nikoskelainen, S., Ouwehand, A., Salminen, S., & Bylund, G. (2001). Protection of rainbow trout (*Oncorhynchus mykiss*) from furunculosis by *Lactobacillus rhamnosus*. *Aquaculture*, *198*(3–4), 229–236.

Nowroozi, J., Mirzaii, M., & Norouzi, M. (2004). Study of *Lactobacillus* as probiotic bacteria. *Iranian Journal of Public Health*, *33*(2), 1–7.

NRC (2011). Nutrient Requirement of Fish and Shrimp. The National Academies Press, Washington DC

Omar, M. A., & Hamdan, A. M. (1998). Processing technologies to improve the quality of oil palm agro-by-products. Organizing Committee, c/o Department of Animal science & technology, College of Agriculture & Life Science, Seoul National University.

Orachunwon, C., Thammasarat, S., & Lohawatanakul, C. (2001). Recent developments in tilapia feeds, proceedings of the Tilapia 2001 International Technical & Trade Conference on Tilapia. ,Kuala Lumpur. In S. Subasinghe and T. Singh (Eds.).: Infofish. pp. 113-122.

Ottesen, O. H., & Olafsen, J. A. (2000). Effects on survival and mucous cell proliferation of Atlantic halibut, *Hippoglossus hippoglossus* L., larvae following microflora manipulation. *Aquaculture*, *187*(3), 225–238.

Pandey, G. (2013). Feed formulation and feeding technology for fishes. *International Research Journal of Pharmacy*, *4*(3), 23–30.

Parker, R. B., (1974). Probiotics, the other half of the antibiotics story. *Animal Nutrition Health,* 29, 4–8

Pérez-Sánchez, T., Ruiz-Zarzuela, I., de Blas, I., & Balcázar, J. L. (2014). Probiotics in aquaculture: a current assessment. *Reviews in Aquaculture*, *6*(3), 133–146.

Popma, T. J., & Lovshin, L. L. (1996). Worldwide prospects for commercial production of tilapia. *Alabama: International Center for Aquaculture and Aquatic Environments*.

Popma, T., & Masser, M. (1999). Tilapia, life history and biology-*Southern Regional Aquaculture Center (SRAC) Publication*.

Prevost, H., & Divies, C. (1988). Continuous pre-fermentation of milk by entrapped yoghurt bacteria. I. Development of the process. *Milk Science International (Germany, FR)*.

Pullin, R. S. V. (1983). Choice of tilapia species for aquaculture. In *International symposium on tilapia in aquaculture*.

Rahman, M. F. A. (2010). Design Formulation of Freshwater Fish Feed from Palm Kernel Cake (PKC). *PhD Thesis*. UMP.

Rana, K. J., Siriwardena, S., & Hasan, M. R. (2009). Impact of rising feed ingredient prices on aquafeeds and aquaculture production. *Food & Agriculture Organization of the United Nations (FAO)*.

Roberfroid, M. (1993). Dietary fiber, inulin, and oligofructose: a review comparing their physiological effects. *Critical Reviews in Food Science & Nutrition*, *33*(2), 103–148.

Roberfroid, M. B. (2005). Introducing inulin-type fructans. *British Journal of Nutrition*, *93*(S1), S13–S25.

Roberfroid, M., Gibson, G. R., Hoyles, L., McCartney, A. L., Rastall, R., Rowland, I., … Stahl, B. (2010). Prebiotic effects: metabolic and health benefits. *British Journal of Nutrition*, *104*(S2), S1–S63.

Robinson, E. H., Li, M. H., & Manning, B. E. (2001). A practical guide to nutrition, feeds, and feeding of catfish (Vol. 1113). Office of Agricultural Communications, Division of Agriculture, Forestry, and Veterinary Medicine, Mississippi State University.

Rodriguez-Estrada, U., Satoh, S., Haga, Y., Fushimi, H., & Sweetman, J. (2013). Effects of inactivated *Enterococcus faecalis* and mannan oligosaccharide and their combination on growth, immunity, and disease protection in rainbow trout. *North American Journal of Aquaculture*, *75*(3), 416–428.

Roslan, M. A. H., Abdullah, N., Murad, N. Z. A., Halmi, M. I. E., Idrus, Z., & Mustafa, S. (2017). Optimisation of Extrusion for Enhancing the Nutritive Value of Palm Kernel Cake Using Response Surface Methodology. *BioResources*, *12*(3), 6679–6697.

Russo, P., López, P., Capozzi, V., De Palencia, P. F., Dueñas, M. T., Spano, G., & Fiocco, D. (2012). Beta-glucans improve growth, viability and colonization of

probiotic microorganisms. *International Journal of Molecular Sciences*, *13*(5), 6026–6039.

Sáenz de Rodrigáñez, M. A., Díaz-Rosales, P., Chabrillón, M., Smidt, H., Arijo, S., León-Rubio, J. M., … Cara, J. B. (2009). Effect of dietary administration of probiotics on growth and intestine functionality of juvenile Senegalese sole (S*olea senegalensis, Kaup* 1858). *Aquaculture Nutrition*, *15*(2), 177–185.

Safari, O., Shahsavani, D., Paolucci, M., & Atash, M. M. S. (2014). Single or combined effects of fructo- and mannan oligosaccharide supplements on the growth performance, nutrient digestibility, immune responses and stress resistance of juvenile narrow clawed crayfish, *Astacus leptodactylus leptodactylus Eschscholtz,* 1823. *Aquaculture*, *432*, 192–203.

Sang, H. M., Kien, N. T., & Thanh Thuy, N. T. (2014). Effects of dietary mannan oligosaccharide on growth, survival, physiological, immunological and gut morphological conditions of black tiger prawn (*Penaeus monodon Fabricius* 1798). *Aquaculture nutrition*, *20*(3), 341-348.

Schillinger, U. (1999). Isolation and identification of *lactobacilli* from novel-type probiotic and mild yoghurts and their stability during refrigerated storage. *International Journal of Food Microbiology*, *47*(1–2), 79–87.

Shah, N. P., & Lankaputhra, W. E. (1997). Improving viability of *Lactobacillus acidophilus* and *Bifidobacterium* spp. in yogurt. *International Dairy Journal*, *7*(5), 349–356.

Shalaby, A. M., Khattab, Y. A., & Abdel Rahman, A. M. (2006). Effects of Garlic (Allium sativum) and chloramphenicol on growth performance, physiological parameters and survival of Nile tilapia (*Oreochromis niloticus*). *Journal of Venomous Animals & Toxins Including Tropical Diseases*, *12*(2), 172–201.

Shelton, W. L. (2002, February). Tilapia culture in the 21st century. In *Tilapia Farming in the 21st Century, Proc. Int. Forum on Tilapia Farming in the 21st Century* (pp. 1-20).

Sheu, T. Y., & Marshall, R. T. (1993). Microentrapment of *lactobacilli* in calcium alginate gels. *Journal of Food Science*, *58*(3), 557–561.

Shi, L.-E., Li, Z.-H., Li, D.-T., Xu, M., Chen, H.-Y., Zhang, Z.-L., & Tang, Z.-X. (2013). Encapsulation of probiotic *Lactobacillus bulgaricus* in alginate–milk microspheres and evaluation of the survival in simulated gastrointestinal conditions. *Journal of Food Engineering*, *117*(1), 99–104.

Shiau, S. Y., & Jan, F. L. (1992). Dietary ascorbic acid requirement of juvenile tilapia *Oreochromis niloticus* x *O. aureus*. *Bulletin of the Japanese Society of Scientific Fisheries (Japan)*, *58*: pp. 671-675.

Shiau, S.Y. (1997). Utilization of carbohydrates in warmwater fish - with particular reference to tilapia, *Oreochromis niloticus x O. aureus*. *Aquaculture. 151*:pp. 79-96.

Shiau, S.-Y. (2002). Tilapia, *Oreochromis* spp. *Nutrient Requirements & Feeding of Finfish for Aquaculture*, 273–292.

Siddiqui, A. Q., Howlander, M. S., & Adam, A. A. (1988). Effects of dietary protein levels on growth, diet conversion and protein utilization in fry and young Nile tilapia, *Oreochromis niloticus*. *Aquaculture. 70*: pp. 63-70.

Siddiqui, A. Q., & Al-Harbi, A. H. (1995). Evaluation of three species of tilapia, red tilapia and a hybrid tilapia as culture species in Saudi Arabia. *Aquaculture*, *138*(1–4), 145–157.

Siddiqui, A. Q., Al Hafedh, S., & Ali, S. A. (1998). Effect of dietary protein level on the reproductive performance of Nile tilapia, *Oreochromis niloticus* (L.). *Aquaculture Research. 29*: pp. 349-358.

Sindhu, S. C., & Khetarpaul, N. (2001). Probiotic Fermentation of Indigenous Food Mixture: Effect on Antinutrients and Digestibility of Starch and Protein. *Journal of Food Composition & Analysis*, *14*(6), 601–609.

Singh, R. R., Majumdar, R. K., & Venkateshwarlu, G. (2014). Optimum extrusion-cooking conditions for improving physical properties of fish-cereal based snacks by response surface methodology. *Journal of Food Science & Technology*, *51*(9), 1827–1836.

Skarstad, K., Steen, H. B., & Boye, E. (1983). Cell cycle parameters of slowly growing *Escherichia coli* B/r studied by flow cytometry. *Journal of Bacteriology*, *154*(2), 656–662.

Sohail, A., Turner, M. S., Coombes, A., Bostrom, T., & Bhandari, B. (2011). Survivability of probiotics encapsulated in alginate gel microbeads using a novel impinging aerosols method. *International Journal of Food Microbiology*, *145*(1), 162–168.

Son, V. M., Chang, C.-C., Wu, M.-C., Guu, Y.-K., Chiu, C.-H., & Cheng, W. (2009). Dietary administration of the probiotic, *Lactobacillus plantarum*, enhanced the growth, innate immune responses, and disease resistance of the grouper *Epinephelus coioides*. *Fish & Shellfish Immunology*, *26*(5), 691–698.

Song, S. K., Beck, B. R., Kim, D., Park, J., Kim, J., Kim, H. D., & Ringø, E. (2014). Prebiotics as immunostimulants in aquaculture: A review. *Fish & Shellfish Immunology*, *40*(1), 40–48.

Sorensen, M. (2015). Nutritional and Physical Quality of Aqua Feeds.

Spanggaard, B., Huber, I., Nielsen, J., Sick, E. B., Pipper, C. B., Martinussen, T., … Gram, L. (2001). The probiotic potential against *vibriosis* of the indigenous microflora of rainbow trout. *Environmental Microbiology*, *3*(12), 755–765.

Standen, B. T., Peggs, D. L., Rawling, M. D., Foey, A., Davies, S. J., Santos, G. A., & Merrifield, D. L. (2016). Dietary administration of a commercial mixed-species probiotic improves growth performance and modulates the intestinal immunity of tilapia, *Oreochromis niloticus*. *Fish & Shellfish Immunology*, *49*, 427–435.

Stickney, R.R. (1997). Tilapia update 1996. *World Aquaculture. 28*: pp. 20-25.

Subasinghe, R. P. (2005). Epidemiological approach to aquatic animal health management: opportunities and challenges for developing countries to increase aquatic production through aquaculture. *Preventive Veterinary Medicine*, *67*(2–3), 117–124.

Sundu, B., Kumar, A., & Dingle, J. (2006). Palm kernel meal in broiler diets: effect on chicken performance and health. *World's Poultry Science Journal*, *62*(2), 316–325.

Syahirah, S. N., Anida, Y., Nazirah, M. Y. H., Ahmad, S. A., Dahalan, F. A., & Khalilah, A. K. (2013). Optimization of *Aloe vera* and alginate as encapsulating matrices for *Lactobacillus acidophilus* using FCCD-RSM approach. In *2013 IEEE 3rd International Conference on System Engineering and Technology* (pp. 43–47).

Tamamdusturi, R., & Yuhana, M. (2016). Administration of microencapsulated probiotic *Bacillus* sp. NP5 and prebiotic mannan oligosaccharide for prevention of *Aeromonas hydrophila* infection on *Pangasianodon hypophthalmus*. *Journal of Fisheries & Aquatic Science*, *11*(1), 67.

Tapia-Paniagua, S. T., Reyes-Becerril, M., Ascencio-Valle, F., Esteban, M. A., Clavijo, E., Balebona, M. C., & Morinigo, M. A. (2011). Modulation of the intestinal microbiota and immune system of farmed *Sparus aurata* by the administration of the yeast *Debaryomyces hansenii* L2 in conjunction with inulin. *Journal of Aquaculture Research & Development*, *1*.

Terrapon, N., Lombard, V., Gilbert, H. J., & Henrissat, B. (2015). Automatic prediction of polysaccharide utilization loci in *Bacteroidetes* species. *Bioinformatics*, *31*(5), 647–655.

Teves, J. F. C., & Ragaza, J. A. (2016). The quest for indigenous aquafeed ingredients: a review. *Reviews in Aquaculture*, *8*(2), 154–171.

Thongdon-A, R., Limsuwan, C., & Chuchird, N. (2012). Seasonality of gill monogeneans in red hybrid tilapia (*Oreochromis* sp.) cage culture systems in central Thailand. *Kasetsart University Fisheries Research Bulletin*, *36*(3), 43–53.

Valente, L. M. P., Cornet, J., Donnay-Moreno, C., Gouygou, J. P., Berge, J. P., Bacelar, M., ... & Cardinal, M. (2011). Quality differences of gilthead sea bream from

distinct production systems in Southern Europe: Intensive, integrated, semi-intensive or extensive systems. *Food Control*, *22*(5), 708-717.

Vendrell, D., Luis Balcázar, J., de Blas, I., Ruiz-Zarzuela, I., Gironés, O., & Luis Múzquiz, J. (2008). Protection of rainbow trout (*Oncorhynchus mykiss*) from *lactococcosis* by probiotic bacteria. *Comparative Immunology, Microbiology & Infectious Diseases*, *31*(4), 337–345.

Verschuere, L., Rombaut, G., Sorgeloos, P., & Verstraete, W. (2000). Probiotic Bacteria as Biological Control Agents in Aquaculture. *Microbiology & Molecular Biology Reviews*, *64*(4), 655–671.

Wang, M., & Lu, M. (2016). Tilapia polyculture: a global review. *Aquaculture Research*, *47*(8), 2363–2374.

Watanabe, W. O., Olla, B. L., Wicklund, R. I., & Head, W. D. (1997). Saltwater culture of the Florida red tilapia and other saline-tolerant tilapias: a review. *Tilapia Aquaculture in the Americas*, *1*, 54-141.

Watanabe, W. O., Losordo, T. M., Fitzsimmons, K., & Hanley, F. (2002). Tilapia production systems in the Americas: technological advances, trends, and challenges. *Reviews in fisheries science*, *10*(3-4), 465-498.

Weaver, K. L., Ivester, P., Chilton, J. A., Wilson, M. D., Pandey, P., & Chilton, F. H. (2008). The content of favorable and unfavorable polyunsaturated fatty acids found in commonly eaten fish. *Journal of the American Dietetic Association*, *108*(7), 1178-1185.

Webster, C. D., & Lim, C. (2006). *Tilapia: biology, culture, and nutrition*. CRC Press.

Winfree, R. A., & Stickney, R. R. (1981). Effects of dietary protein and energy on growth, feed conversion efficiency and body composition of Tilapia *aurea*. *The Journal of nutrition*, *111*(6), 1001-1012.

Wu, Z., Yu, Y., Chen, X., Liu, H., Yuan, J., Shi, Y., & Chen, X. (2014). Effect of prebiotic konjac mannanoligosaccharide on growth performances, intestinal microflora, and digestive enzyme activities in yellow catfish, *Pelteobagrus fulvidraco*. *Fish Physiology & Biochemistry*, *40*(3), 763–771.

Yanbo, W., & Zirong, X. (2006). Effect of probiotics for common carp (*Cyprinus carpio*) based on growth performance and digestive enzyme activities. *Animal Feed Science & Technology*, *127*(3–4), 283–292.

Ye, J.-D., Wang, K., Li, F.-D., & Sun, Y.-Z. (2011). Single or combined effects of fructo- and mannan oligosaccharide supplements and *Bacillus clausii* on the growth, feed utilization, body composition, digestive enzyme activity, innate immune response and lipid metabolism of the Japanese flounder P*aralichthys olivaceus*. *Aquaculture Nutrition*, *17*(4), e902–e911.

You, K. G., Bong, C. W., & Lee, C. W. (2016). Antibiotic resistance and plasmid profiling of *Vibrio* spp. in tropical waters of Peninsular Malaysia. *Environmental Monitoring & Assessment*, *188*(3), 171.

Zhou, X., Tian, Z., Wang, Y., & Li, W. (2010). Effect of treatment with probiotics as water additives on tilapia (*Oreochromis niloticus*) growth performance and immune response. *Fish Physiology & Biochemistry*, *36*(3), 501–509.

Zonneveld, N., & Fadholi, R. (1991). Feed intake and growth of red tilapia at different stocking densities in ponds in Indonesia. *Aquaculture*, *99*(1), 83–94.