



Research findings from the use of probiotics in tilapia aquaculture: A review



Ngo Van Hai*

Sustainable Aquatic Resources and Biotechnology, Curtin University of Technology, 1 Turner Avenue, Technology Park, Bentley, WA 6102, Australia

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ABSTRACT

This study aims to present research findings from the use of probiotics in tilapia aquaculture. In omnivorous species of tilapia aquaculture, intestines and gonads, rearing water and sediments or even commercial products, can be sources for acquiring appropriate probiotics. Administration of probiotics varies from direct oral/water routine to feed additives, of which the latter is most commonly used. Probiotic applications can be either mono or multiple strains. Dosage and duration of time are significant factors in providing desired results. As probiotics have been proven to be either immune enhancers and/or growth promoters in aquatic animals, several modes of actions of probiotics in enhancement of immune responses, and an improvement of growth and survival rates of tilapia are presented, while the effects of others are not yet understood to the same degree as for other fish species. Some points extracted from the research findings are emphasised for further investigation and development.

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1. Introduction

Tilapia is the second most farmed fish world-wide and its production has quadrupled over the past decade because of its suitability for aquaculture, marketability and stable market prices [1]. Generally, fish are continuously exposed to a wide range of microorganisms present in the environment [2]. Being an omnivorous species, both potentially probiotic and pathogenic bacteria viz. *Bacillus* sp., *Lactobacillus brevis*, *Lactobacillus collinoides*, *Lactobacillus coryniformis*, *Lactobacillus farciminis*, *Vibrio* sp. and *Pseudomonas fluorescens* were found in tilapia gastrointestinal tract, rearing water and sediment, of which higher abundances of *P. fluorescens*, *Bacillus* sp., *L. brevis* and *L. collinoides* presented in the fish guts [3]. Similar to other fish farming, tilapia culture has also been facing economic losses because of diseases.

As microbial disease in the aquaculture industry implies serious financial loss [4–6], antimicrobials, parasiticides, and feed additives, are used to improve the health status of cultured organisms and to prevent or treat disease outbreaks [7]. The use of antibiotics to control fish disease is also one of the constraints in tilapia farming [8]. Therefore, the use of probiotics as an alternative

strategy has been receiving increasing attention world-wide in tilapia aquaculture.

Although probiotics offer a promising alternative to the use of chemicals and antibiotics in aquatic animals [9], and to assist in the protection of aquacultured species from diseases, the benefits to the hosts by the use of probiotics in aquaculture need to be considered. Various factors like source, dose and duration of supplementation of probiotics can affect the immunomodulatory activity of probiotics. Therefore, appropriate administration methods help to provide favourable conditions for probiotics to perform well. Understanding the modes of action along with appropriate application methods may be the key for the use of probiotics in aquatic systems. Although the exact mode of action of probiotics is yet to be established in fish, probiotics often exert host specific and strain specific differences in their activities.

Indeed, although many studies on probiotics have been published in fish and shellfish aquaculture world-wide, there are fewer publications on probiotics in tilapia. This study aims to review research findings of using probiotics only for the culture of omnivorous species of tilapia, in which a critical evaluation is presented from a screen of potential probiotics to an evaluation of their effectiveness to the hosts. Moreover, some ideas from the research findings are identified for further investigation and development as the use of probiotics can be a sustainable and viable strategy for successful aquaculture.

* Tel.: +61 8 9266 9806; fax: +61 8 9266 4422.

E-mail address: ngovanhai@yahoo.com.

2. Source of tilapia and probiotics

2.1. Tilapia

Tilapia is a euryhaline fish species, but mainly found in fresh-water and less commonly found in brackish water. Recently, several modern technologies, new approaches and alternative methods, including probiotics, have been applied to improve the production as well as quality of this species [1,10–13]. Among tilapias, Nile tilapia, *Oreochromis niloticus* (L.) is the most important species, and its growth performance and diseases resistance are critical keys for its culture expansion [14,15].

Studies on the effects of probiotics on tilapia were carried out mainly on Nile tilapia [13,16], Mozambique tilapia (*Oreochromis mossambicus*) [17], and hybrid tilapia between *O. mossambicus* × *O. niloticus* [18] or between *O. niloticus* ♀ × *Oreochromis aureus* ♂ [19]. There are few studies on blue tilapia (*O. aureus*), and no evidence on genetically improved farmed tilapia (GIFT strain), which is commonly preferred in commercial tilapia farming recently. It may be because the GIFT strain is also Nile tilapia. Therefore, authors may not distinguish the GIFT strain from Nile tilapia. In addition, effects of probiotics on Galilee tilapia, *Sarotherodon galilaeus* (L.), was also studied by Abdel-Tawwab et al. [20].

2.2. Sources of probiotics

A wide range of micro-organisms including Gram-negative and Gram-positive bacteria have been used as probiotics in aquaculture such as *Lactobacillus*, *Lactococcus*, *Leuconostoc*, *Enterococcus*, *Carnobacterium*, *Shewanella*, *Bacillus*, *Aeromonas*, *Vibrio*, *Enterobacter*, *Pseudomonas*, *Clostridium*, and *Saccharomyces* species [21]. These organisms are often in the digestive tracts of the host animal [22]. Likewise, potential probiotics used for tilapia culture were isolated from intestines of tilapia and their culture system (rearing water and sediment) [10,13,14,23,24] or even their gonads [14]. *Bacillus amyloliquefaciens* isolated from fish gut microflora was used as probiotics in Nile tilapia [25]. Interestingly, probiotic *P. fluorescens* isolated from the intestines of brackish-water Nile tilapia conferred beneficial effects for freshwater Nile tilapia [24]. Among the promising probiotics in intestinal tracts, rearing water and sediment, the probiotic composition in gastrointestinal tract of tilapia was more similar to those in the water than those in the sediment [3].

Probiotics have been widely and effectively used in human and veterinary medicine. They include lactic acid bacteria (LAB), putative *Lactobacillus* spp [26]. In the same way, LAB is also used commonly in tilapia aquaculture [10]. For example, probiotics *Lactobacillus acidophilus* [27–29], *L. brevis* [28], *Lactobacillus plantarum* [30] are also used as immune enhancers for Nile tilapia. Among probiotic species employed in aquaculture, *Bacillus* spp. is likely the most widely used as a probiotic to enhance growth performance, innate immune responses, and disease resistance [19], where *Bacillus subtilis* is commonly employed [10,16,19,27,31,32]. *Bacillus pumilus* [33] and *Bacillus amyloliquefaciens* [25] are also used as probiotics for Nile tilapia aquaculture.

Other probiotic bacteria proven to bring benefits to tilapia include *Aspergillus oryzae* [32], *Bifidobacterium bifiduim* [29], *Enterococcus faecium* [34], *Micrococcus luteus* [14], *Pediococcus acidilactici* [35], *P. fluorescens* [24]. *Streptococcus salivarius* subsp. *thermophilus* (previous name *Streptococcus thermophilus*) [29]. Baker's yeast (*Saccharomyces cerevisiae*) has been recognized as a potential probiotic for Nile tilapia [15,32,36,37] and Galilee tilapia [20]. Live microalgae also act as a probiotic for tilapia. For instance, a spirulina (*Arthrospira platensis*) supplemented diet was an

alternative method to antibiotics for disease prevention in Nile tilapia aquaculture [8]. Available commercial probiotic products are widely employed in tilapia culture [16,18,33,38].

Controversially, while some bacteria have proven to be opportunistic pathogens for one fish species, they can be used effectively as probiotics in another species. *Citrobacter freundii* and *P. fluorescens* has been associated with fish diseases [39], but they are potential probiotics in Nile tilapia [13,24,27]. A bacterium is harmful to one aquatic animal, but they can also bring benefits to other species as probiotics. Probiotics are, therefore, species specific for appropriate fish species. The normal microbial flora population, including beneficial varieties, in the digestive tract, may be killed or inhibited when exposed to oral chemotherapy [35]. This is particular pertinent in relation to tilapia, which, being an omnivorous fish species, contact a diverse range of bacteria in their environment. Therefore, application methods play a key role in providing favourable conditions for probiotics to bring benefits to the hosts.

3. Application and administration methods

3.1. Feed or water additives

As a probiotic can be administered via the feed or to the rearing water in aquaculture [40], administration of probiotics in tilapia culture is also through the feed as feed additives such as i) mixture with feed viz., pellets, crumbles, granules, flakes or microencapsulation [17], and ii) bioencapsulation with natural live feed organisms as probiotic-enrichment [41]. Feed additives are the most commonly used in aquaculture [42–46] because, most probiotics are designed to be mixed with feed [47]. Probiotics can also administered directly into the rearing water of tilapia aquaculture [10]. There is no evidence to prove which application method of feed or water additive is better in tilapia aquaculture.

3.2. Single and combination

Probiotics can be applied singly or in combination [48–52]. Likewise, single supplementation either *L. acidophilus* or *Bifidobacterium bifiduim* with feed protected Nile tilapia completely from an *Aeromonas hydrophila* challenge [29]. Administration of either individual or combined probiotics *Bacillus* sp. and LAB increased the survival and growth performance in Nile tilapia [10]. A combination of *S. thermophilus*, *L. acidophilus*, *Bifidobacterium bifiduim* eliminated the mortality of Nile tilapia from an *A. hydrophila* challenge [29]. A diet supplemented with a combination of probiotics of *B. subtilis*, *S. cerevisiae* and *A. oryzae* increased respiratory burst activity, erythrocyte fragility and levels of white blood cells of Nile tilapia [32].

In addition, probiotics based on a single strain are less effective than those based on mixed strains [46,53]. Along the same lines, the mixtures of *B. subtilis* and *L. acidophilus* enhanced higher haemocrit values and serum bacteriocidal activity compared to those exposed to single cultures in Nile tilapia [27]. Although a combination of probiotics has proved to bring more benefits to the hosts than a single one does, a combination does not always provide advantages on tilapia. Administration of a combination of probiotics of *B. subtilis*, *S. cerevisiae* and *A. oryzae* had no effect on the growth rates of Nile tilapia, although the fish fed these probiotics individually had better feed conversion [32].

3.3. Dosage

A diverse range of dosages has been applied in the use of probiotics in tilapia aquaculture, of which mixing with the feed

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