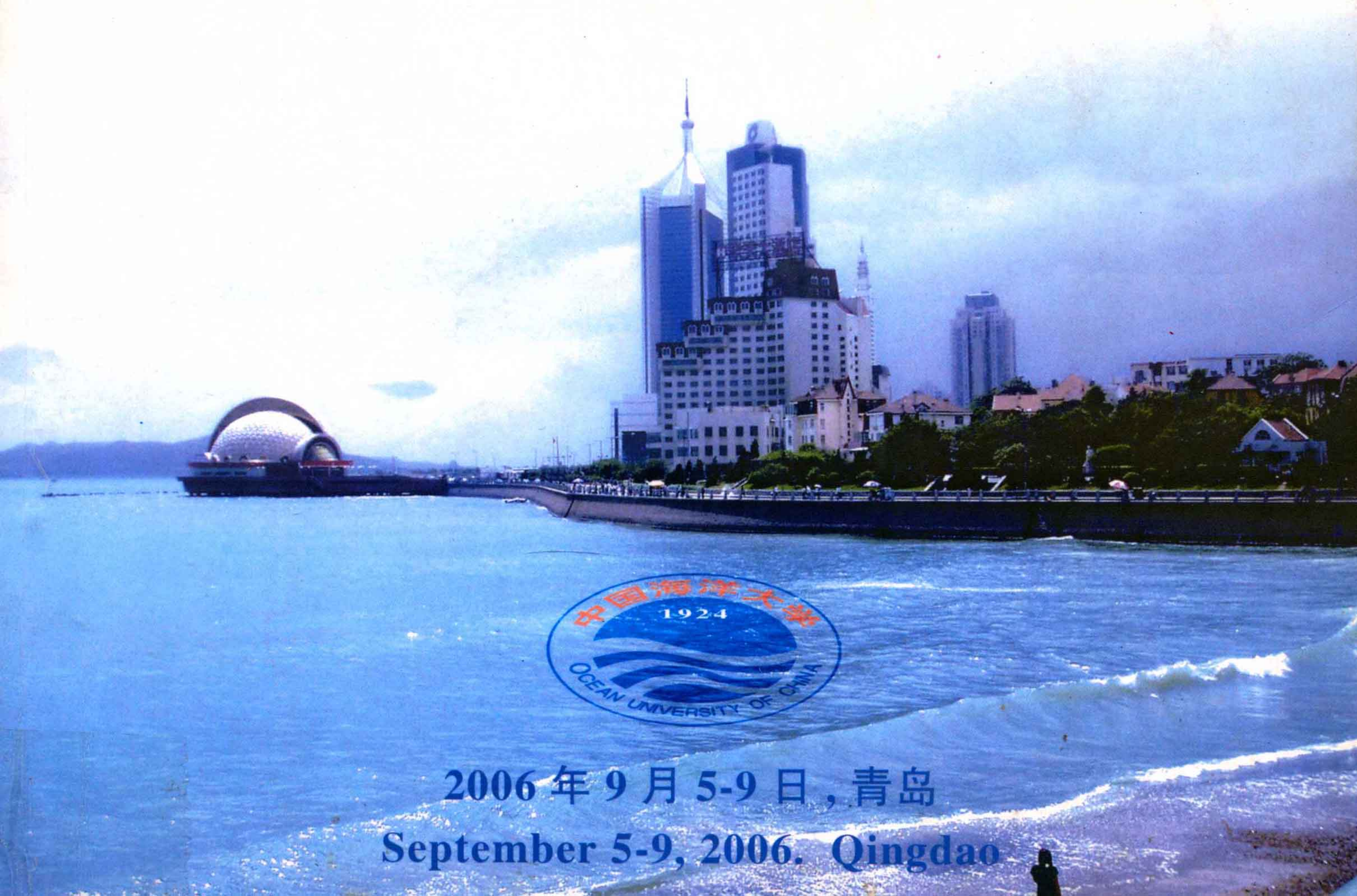
第六届世界华人鱼虾营养学术研讨会

The Sixth Symposium of World's Chinese Scientists on Nutrition and Feeding of Finfish and Shellfish

论文集

PROCEEDINGS



2006年9月5-9日，青岛

September 5-9, 2006. Qingdao

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论 文 集

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主办单位：中国水产学会水产动物营养与饲料专业委员会

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Proceedings of the 6th Symposium of World's Chinese Scientists on Nutrition and Feeding of Finfish and Shellfish

Editor in Chief: Kangsen Mai

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序

九月，一个收获成功，分享喜悦的季节。青岛，一个充满诗情画意，碧海蓝天、红瓦绿树的美丽海滨城市。也就是在这样的一个季节，2006 年 9 月 5—9 日，来自中国大陆、台湾、美国、法国、荷兰、丹麦、泰国、缅甸和日本等国家和地区近 600 多名华人科学家、企业家和管理者的代表，在“营养、饲料与水产品质量及食品安全”这一主题的感召下，齐聚青岛参加“第六届世界华人鱼虾营养学术研讨会”。另外，还有多名本领域世界顶尖的非华裔科学家和企业家出席大会并做了精彩报告。他们包括：来自加拿大的国际鱼类营养学术研讨会学术委员会主席 Santosh Lall 博士，法国教育和科学研究联合部水生生物学部鱼类营养实验室主任 Sachi Kaushik 博士，丹麦宝马饲料集团总裁 Niels Alsted 博士，荷兰 Skretting 有限公司营养部经理 Arjen Roem 博士等。

本次是系列会议由三年一届改为两年一届后的第一届，设定了蛋白质与氨基酸、质量和食品安全等 9 个专题，共有 195 篇学术论文参加了交流。大会特别设立了“水产饲料企业家沙龙”，邀请国内外著名饲料企业家就“挑战、机遇、企业健康持续发展”这一主题进行了精彩的论述，得到了与会代表的一致好评。

由李爱杰先生倡导，应广大与会代表要求，组委会决定出版《第六届世界华人鱼虾营养学术研讨会论文集》。本着自愿赐稿、文责自负的原则，共收集论文 80 篇，按照会议期间报告先后排序付印。请诸位同仁鉴读。

第六届世华会的胜利召开并取得圆满成功，是全体同仁共同努力的结果。我们由衷地感谢以广东恒兴集团为首的本届世华会合作伙伴，没有他们强有力的支持，大会不可能取得如此成功。同时，我们必须感谢全体组委会成员、全体学术指导委员会成员、全体顾问委员会成员，以及全体大会工作人员，是他们为大会的成功举办而辛勤劳动、默默奉献。

自 1992 年第一届世华会以来，我国水产动物营养与饲料领域的教学、科研和生产突飞猛进，相关行业生机勃勃，使我们成为世界当之无愧的水产养殖和水产饲料工业的头号大国、强国。体现了世华会对我国水产动物营养的学科建设和饲料产业发展的巨大推动作用。2006 年 5 月在法国举行的“第十二届国际鱼类营养学术研讨会”上，决定将 2010 年的“第十四届国际鱼类营养学术研讨会”交中国主办，在青岛举行。这表明我们在该领域所做的工作也逐步得到了世界同行的高度认可。届时，欢迎各位同仁故地重游，到青岛来一起分享这一国际盛会。

在我们手捧论文集再次品尝相聚的甜蜜，回味交流的喜悦的时候；在我们从相聚到分手，为共同的事业而去完成各自目标的时候；第七届世华会的脚步声离我们越来越近，又是一个值得期待的日子。让我们带着劳动的硕果，2008 聚首北京！

2007 年 7 月 6 日于中国海洋大学

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Vitamin research in tilapia*

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ABSTRACT

Vitamins are organic substances that are essential for growth, health, reproduction and maintenance in animals, but required in small amounts. Since fish cannot synthesize vitamins at all or can only synthesize in insufficient quantity for normal development, growth and maintenance, they must be supplied in the diet. In comparison to terrestrial animals, the information available on vitamin requirement of aquatic species still lacks depth. Other than the 13 known vitamins, i.e. thiamin, riboflavin, niacin, pantothenic acid, biotin, folic acid, vitamin B_6, B_{12}, C, A, D, E and K, their requirements have been quantified in tilapia, the essentiality of choline and inositol for tilapia have also been demonstrated. Vitamin E and B_6 requirements for tilapia are closely related to dietary lipid and protein concentrations, respectively. 42-44 and 60-66 mg vitamin E/kg diet are required for maximal growth of tilapia fed diets with 5 and 12% lipid, respectively; whereas, 1.7-9.5 and 15.0-16.5 mg vitamin B_6/kg diet are required for tilapia fed diets with 28 and 36% protein, respectively. Niacin requirements in tilapia varies with the carbohydrate source in diet. Optimum dietary levels of niacin for maximum growth have been reported to be 26 mg/kg diet for tilapia fed a glucose diet, whereas 121 mg/kg diet is needed for fish fed a dextrin diet. Tilapia produces vitamin B_{12} in their gastrointestinal tract through bacterial synthesis. Thus, no dietary B_{12} is needed for tilapia. Vitamin C (L-ascorbic acid, AA) requirements of tilapia is 79 mg AA/kg diet. When vitamin C stabilizers, L-ascorbyl-2-sulfate (C2S), L-ascorbyl-2-monophosphate-Mg (C2MP-Mg) and L-ascorbyl-2-monophosphate-Na (C2MP-Na), are used as the vitamin C source, the requirement level are 20-23, 17-20 and 16 mg AA/kg diet, respectively. Dietary vitamin A requirements of tilapia is 5,850 to 6,970 IU/kg diet. Tilapia is able to utilize β-carotene to fulfill the dietary vitamin A requirements. The conversion ratio by β-carotene to vitamin A is approximately 19:1.

Key Words: tilapia; vitamin requirement; nutrition

1 Introduction

Tilapias are mainly lacustrine fish which are well-adapted to enclosed water. They are fast growing, resistant to disease and handling, easy to reproduce in capacity, and are able to tolerate a wide range of environmental conditions. They are widely cultured in tropical and subtropical regions of the world and constitute the third largest group of farmed finfish, with an annual growth rate of about 11.5% [1]. Global production of farmed tilapia has increased more than four-fold since 1984, from 550,327 m.t. to 2,543,017 m.t., representing 4.28% of total farmed finfish in 2004 [2].

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Most cultured tilapias are grouped into two genera [3]: *Tilapia*, which are macrophagous and substrate-spawners, and *Oreochromis*, which are microphagous and mouth-brooders. The main cultured species are *Oreochromis niloticus*, *O. aureus*, hybrid *O. niloticus* × *O. aureus*, *O. mossambicus* and *Tilapia zilli*. For the mouthbrooders of the *Oreochromis* genus, there exists a marked delay in the growth of females, and monosex culture of males is preferred. Thus, it is important to indicate the sex of the cultured fish, and whether sex control was obtained through manual sorting, sex-reversal by hormone treatment, or hybridization.

Originally, for most of the tilapia industry, ponds were fertilized to promote growth of prey items, and formulated feeds were supplemental. Vitamin supplements are often not included in practical diets for tilapias stocked at moderate densities in fertilized ponds. As the industry expands and technology development continues, traditional extensive culture of tilapia is being replaced by semi-intensive and intensive production system, the notion that vitamin needs could always be satisfied through the consumption of natural prey items from the pond environment became questionable. As these alternative sources of nutrients became relatively limited, culturists added a range of vitamins to formulated feeds to ensure requirements for these nutrients were met.

Research on vitamin requirements of tilapia begins in 1982. Since 1990, progress has been substantial. Today nearly all the vitamin requirements have been quantified. Table 1 presents the vitamin requirements of various tilapia.

2 Water-soluble vitamins

2.1 Thiamin

Thiamin was the first vitamin to be recognized. In animal tissue, thiamin occurs predominantly in a di-phosphate form known as thiamin pyrophosphate (TPP). TPP is an essential cofactor for a number of important enzymatic steps in energy production, including both decarboxylations and transketolase reactions.

Thiamin deficiency signs observed in red hybrid tilapia (*O. mossambicus* × *O. niloticus*) fingerlings cultured in sea water (32 p.p.t. salinity) were reduced growth and feed efficiency and a low haematocrit. A dietary thiamin level of 2.5 mg/kg of diet was sufficient for maximum growth and prevention of deficiency signs [4].

2.2 Riboflavin

Widely distributed in both plant and animal feedstuffs, riboflavin is generally found complexed with proteins as flavin nucleotides. Within cells, flavin mononucleotide and flavin adenine dinucleotide are typically linked with other organic components into flavoproteins that interact in the metabolism of protein, fat, and carbohydrates. The riboflavin occurring in these enzyme complexes acts as an intermediary in the transfer of electrons in biological oxidation-reduction reactions.

Typically deficiency signs reported for tilapias fed a riboflavin-free diet were anorexia, poor growth, high mortality, fin erosion, loss of normal body colour, short body dwarfism and lens cataracts. The dietary riboflavin requirements were 6 mg/kg of diet for juvenile *O. aureus* grown in fresh water [5] and 5 mg/kg of diet for *O. mossambicus* × *O. niloticus* grown in 32 p.p.t. sea water [6].

2.3 Vitamin B_6

Vitamin B_6 in the form of pyridoxal phosphate participates as a prosthetic group of enzymes in a large number of metabolic reactions, particularly those associated with the metabolism of proteins or amino acids.

Fish fed a diet without vitamin B_6 supplementation developed abnormal neurological signs, anorexia, ataxia, convulsions, caudal fin erosion, mouth lesions, hyperirritability, poor growth and high mortality. Weight gain and hepatic alanine aminotransferase activity analyzed by broken-line regression indicated that the optimum dietary vitamin B_6 requirement in juvenile *O. niloticus* × *O. aureus* reared in fresh water were 1.7-9.5 mg/kg of diet and 15.0-16.5 mg/kg of diet containing 28% and 36% protein, respectively [7]. A dietary vitamin B_6 level of 3 mg/kg of diet was reported to be adequate for *O. mossambicus* × *O. niloticus* fed 38% protein diets and reared in sea water [8].

2.4 Vitamin B_{12}

Vitamin B_{12} is the generic name for a group of cobalt-containing compounds called cobalamins, that have the biological activity of cyanocobalamin. Vitamin B_{12} dependent enzymes play key roles in the synthesis of nucleic acids and proteins and in the transfer of methyl units in carbohydrate and fat metabolism.

Tilapia produced vitamin B_{12} in their gastrointestinal tract through bacterial synthesis and did not have a dietary requirement for this vitamin [9-11].

2.5 Niacin

Niacin is a vital part of the coenzymes needed to release energy from carbohydrate. The niacin (3-pyridine carboxylic acid and various derivatives) requirement for animal can be met in a number of ways. Some niacin can be synthesized from the amino acid tryptophan. This biosynthesis occurs not only in gut microbes but also in most species of multicellular animals. Synthesis can supply a substantial portion of the total requirement in some animals, however, animal species vary in this ability. Fish apparently do not effectively synthesize niacin as suggested by the relatively rapid development of deficiency symptoms when they are reared on a niacin-free diet [12]. Niacin synthesis from tryptophan has yet to be quantified for tilapia.

Niacin is a dietary essential for *O. niloticus* × *O. aureus* hybrid but the level required varies depending on the source of dietary carbohydrate. Optimum dietary level for maximum growth have been reported to be 26 mg niacin/kg of diet for fish fed a glucose diet and 121 mg niacin/kg of diet for fish fed a dextrin diet. Fish deprived of dietary niacin developed haemorrhages, a deformed snout, gill odema and skin, fin and mouth lesions [13].

2.6 Biotin

Biotin is a coenzyme for several CO_2 fixing enzymes such as pyruvate carboxylase and acetyl CoA carbozylase. Because these enzymes have a role in gluconeogenesis, fatty acid synthesis and degeneration, and function of the tricarboxylic acid cycle, then biotin is important for the metabolism of amino acids, carbohydrate and lipids.

The dietary biotin requirement for maximum growth of *O. niloticus* × *O. aureus* have been estimated to be 0.06 mg/kg of diet [14].

2.7 Folic acid

Folic acid, when converted to active tetrahydrofolate coenzymes, functions as a one-carbon donor or acceptor in a variety of reactions involved in amino acid and nucleotide metabolism. It is necessary for normal cell division and multiplication, and a deficiency of folic acid is characterized in most animals and in humans by impaired hematopoiesis.

An analysis of the weight gain percentage by broken-line regression indicates that the adequate dietary folic acid requirement of *O. niloticus* × *O. aureus* is 0.82 mg/kg of diet [15].

2.8 Pantothenic acid

Pantothenic acid functions as a part of the coenzyme A molecule in the metabolic release of energy from all three energy-providing nutrients, carbohydrate, fat, and protein, by way of the tricarboxylic acid cycle.

Pantothenic acid deficiency causes poor growth, haemorrhage, sluggishness, high mortality, anemia and serve hyperplasia of the epithelial cells of gill lamellae in *O. aureus*. A dietary level of 10 mg of calcium-pantothenate/kg of diet is sufficient to prevent these deficiency signs [16]. Roem *et al.* [17] reported that *O. aureus* could satisfy their requirement for pantothenic acid by feeding on bacteria in a recirculating system.

2.9 Choline

Choline, a vitamin-like nutrient, is an important component of the phospholipid lecithin and certain other complex lipids. It serves as a source of labile methyl groups for the synthesis of various methylated metabolites and as a precursor of acetylacholine. However, the studies with fish identified choline as essential for maximum weight gain [18-20].

While it was suggested that a high level of dietary methionine may have partially satisfied choline requirement in *O. aureus* [17, 21], Shiau and Lo [22] established that the optimum dietary choline requirement for *O. niloticus* × *O. aureus* is 1,000 mg/kg of diet.

2.10 *Myo*-inositol

Myo-inositol is the most prevalent naturally occurring biologically active isomer of inositol and exists as a structural component of phosphatidylinositol in cell membranes. It is also a part of the phosphoinositide system, a signal transduction pathway stimulated by certain hormones, neurotransmitters, or growth factors. Inositol is classified as a vitamin-like nutrient and often a supplement to aquatic feeds.

Shiau and Su [23] indicated that the intestinal microbial synthesis is not a significant source of inositol for tilapia and that the requirement for dietary *myo*-inositol in growing *O. niloticus* × *O. aureus* is 400 mg/kg of diet.

2.11 Vitamin C

Vitamin C (ascorbic acid, AA) acts as a biological reducing agent for hydrogen transport. It is involved in many enzyme systems for hydroxylation, i.e., hydroxylation of tryptophan, tyrosine, and praline. Vitamin C is necessary for the formation of collagen and normal cartilage. Vitamin C is an indispensable nutrient for fish, as they cannot synthesize this nutrient due to the lack of enzyme L-gulonolactone oxidase (EC 1.1.3.8), therefore they depend on exogenous supply through dietary source.

Tilapias showed classical vitamin C deficiency signs when fed a vitamin-deficient diet in the absence of natural foods. The requirement for normal growth of *O. aureus* has been reported to be 50 mg AA/kg of diet [24]. In juvenile *O. niloticus* × *O. aureus*, a dietary level of 79 mg AA/kg of diet is needed for