

学校编码: 10384

分类号 _____ 密级 _____

学号: 20051302087

UDC _____

厦 门 大 学

硕 士 学 位 论 文

凡纳滨对虾N-乙酰- β -D-氨基葡萄糖苷酶
活力调控的研究

Research on the activity regulation of N-Acetyl- β -D-
glucosaminidase from *Litopenaeus vannamei*

杜娟

指导教师姓名: 陈清西 教授

专 业 名 称: 生物化学与分子生物学

论文提交日期: 2008 年 4 月 21 日

论文答辩时间: 2008 年 5 月 29 日

学位授予日期: 2008 年 月 日

答辩委员会主席: 黄耀坚

评 阅 人: _____

2008 年 5 月 20 日

厦门大学学位论文原创性声明

兹提交的学位论文，是本人在导师指导下独立完成的研究成果。本人在论文写作中参考的其他个人或集体的研究成果，均在文中以明确方式标明。本人依法享有和承担由此论文而产生的权利和责任。

声明人（签名）：

2008年5月20日

厦门大学学位论文著作权使用声明

本人完全了解厦门大学有关保留、使用学位论文的规定。厦门大学有权保留并向国家主管部门或其指定机构送交论文的纸质版和电子版,有权将学位论文用于非赢利目的的少量复制并允许论文进入学校图书馆被查阅,有权将学位论文的内容编入有关数据库进行检索,有权将学位论文的标题和摘要汇编出版。保密的学位论文在解密后适用本规定。

本学位论文属于

- 1、保密 (), 在 _____ 年解密后适用本授权书。
- 2、不保密 ()

(请在以上相应括号内打“√”)

作者签名:

日期: 2008 年 5 月 20 日

导师签名:

日期: 2008 年 5 月 20 日

目 录

中文摘要.....	11
英文摘要.....	13
第一章 前言.....	15
1.1 对虾养殖及凡纳滨对虾概况.....	15
1.1.1 凡纳滨对虾简介.....	15
1.1.2 对虾养殖现状与存在问题.....	16
1.1.2.1 对虾主要疾病及防治手段、诊断方法.....	17
1.1.2.1.1 对虾的主要疾病.....	17
1.1.2.1.2 对虾桃拉综合症病毒病（TUARA）的研究现状.....	18
1.1.2.1.3 对虾疾病的防治手段.....	19
1.1.2.2 重金属污染概述.....	20
1.2 几丁质与几丁质酶系的研究概况.....	21
1.2.1 几丁质简介.....	21
1.2.2 几丁质酶系的研究概况.....	22
1.2.2.1 几丁质酶.....	22
1.2.2.2 N-乙酰-β-D-氨基葡萄糖苷酶.....	23
1.2.3 N-乙酰-β-D-氨基葡萄糖苷酶的应用研究及对凡纳滨对虾的意义.....	23
1.3 本论文的研究意义与研究内容.....	24
第二章 实验材料、仪器与方法.....	26
2.1 材料与试剂.....	26
2.2 仪器.....	27
2.3 方法.....	27
2.3.1 蛋白质浓度的测定.....	27
2.3.2 酶活力和比活力的测定.....	27
2.3.3 酶的分离纯化.....	28

2.3.3.1 凡纳滨对虾内脏酶、壳膜酶的分离纯化.....	28
2.3.3.2 不同生长期和患红体病凡纳滨对虾粗酶的提取.....	29
2.3.4 酶催化反应的动力学性质研究.....	29
2.3.4.1 酶催化pNP-NAG水解的动力学参数测定.....	29
2.3.4.2 酶催化pNP-NAG水解反应的活化能测定.....	29
2.3.4.3 酶催化反应最适pH的测定.....	30
2.3.4.4 酶催化反应最适温度的测定.....	30
2.3.4.5 酶的pH稳定性测定.....	30
2.3.4.6 酶的热稳定性测定.....	30
2.3.5 效应物对酶活力的影响.....	30
2.3.5.1 金属离子对酶活力的影响.....	30
2.3.5.2 有机溶剂、有机污染物对酶活力的影响.....	30
2.3.5.3 养殖药物对酶活力的影响.....	31
2.3.5.4 效应物对酶活力的抑制动力学测定.....	31
2.3.6 重金属离子对凡纳滨对虾 NAGase 活力的影响.....	31
2.3.6.1 重金属离子梯度的设置.....	31
2.3.6.2 数据的处理和分析.....	32
第三章 实验结果	33
3.1 健康虾与患红体病虾的 NAGase 的比较	33
3.1.1 健康虾与患红体病虾的粗 NAGase 比活力比较.....	33
3.1.2 健康虾与患红体病虾的 NAGase 基本性质比较.....	33
3.1.2.1 健康虾与患红体病虾的壳膜和内脏 NAGase 的最适 pH 比较.....	33
3.1.2.2 健康及患红体病虾的壳膜和内脏 NAGase 的 pH 稳定性比较.....	34
3.1.2.3 健康与患红体病对虾的壳膜和内脏 NAGase 的最适温度比较.....	36
3.1.2.4 健康与患红体病对虾的壳膜和内脏 NAGase 的热稳定性比较.....	37
3.1.2.5 健康与患红体病对虾的壳膜和内脏 NAGase 催化 pNP-NAG 水解的 动力学参数的测定.....	39
3.1.2.6 健康与患红体病对虾的壳膜和内脏 NAGase 的活化能比较.....	41

3.1.3 几种金属离子对健康虾与患红体病虾的 NAGase 活力影响比较.....	42
3.1.3.1 Cu ²⁺ 对健康虾与患红体病虾的 NAGase 活力影响比较.....	42
3.1.3.2 Zn ²⁺ 对健康虾与患红体病虾的 NAGase 活力影响比较.....	43
3.1.3.3 Hg ²⁺ 对健康虾与患红体病虾的 NAGase 活力影响比较.....	45
3.1.3.4 Cd ²⁺ 对健康虾与患红体病虾的 NAGase 活力影响比较.....	46
3.1.3.5 Pb ²⁺ 对健康虾与患红体病虾的 NAGase 活力影响比较.....	48
3.1.3.6 Al ³⁺ 对健康虾与患红体病虾的 NAGase 活力影响比较.....	49
3.1.4 几种有机溶剂对健康虾与患红体病虾的 NAGase 活力影响比较.....	51
3.1.4.1 乙醇对健康虾与患红体病虾的 NAGase 活力影响比较.....	51
3.1.4.2 甲醛对健康虾与患红体病虾的 NAGase 活力影响比较.....	52
3.1.4.3 苯酚对健康虾与患红体病虾的 NAGase 活力影响比较.....	54
3.1.4.4 甲醇对健康虾与患红体病虾的 NAGase 活力影响比较.....	55
3.1.4.5 二氧六环对健康虾与患红体病虾的 NAGase 活力影响比较.....	57
3.1.4.6 DMF 对健康虾与患红体病虾的 NAGase 活力影响比较.....	58
3.1.4.7 DMSO 对健康虾与患红体病虾的 NAGase 活力影响比较.....	59
3.1.5 几种变性剂对健康虾与患红体病虾的 NAGase 活力影响比较.....	61
3.1.5.1 NBS 对健康虾与患红体病虾的 NAGase 活力影响比较.....	61
3.1.5.2 SDS 对健康虾与患红体病虾的 NAGase 活力影响比较.....	62
3.1.5.3 Urea 对健康虾与患红体病虾的 NAGase 活力影响比较.....	64
3.2 对虾养殖常用药物对酶的影响及动力学研究.....	66
3.2.1 消毒药物对酶活力的影响.....	66
3.2.1.1 氯制剂类消毒药物对酶活力的影响与抑制机理的研究.....	66
3.2.1.2 季铵盐类消毒药物对酶活力的影响.....	70
3.2.1.3 戊二醛对酶活力的影响.....	71
3.2.2 几种抗生素类药物对酶活力的影响.....	72
3.2.3 几种内服抗菌药物对酶活力的影响.....	74
3.2.3.1 盐酸环丙沙星对酶活力的影响.....	74
3.2.3.2 诺氟沙星对酶的抑制类型与抑制常数.....	76
3.2.3.3 磺胺甲噁唑对酶的抑制类型与抑制常数.....	78
3.2.3.4 磺胺嘧啶对酶活力的影响.....	82

3.2.4 维生素对酶活力的影响.....	83
3.2.4.1 VB ₁ 和 VB ₆ 对对虾 NAGase 活力的影响.....	84
3.2.4.2 抗坏血酸对对虾 NAGase 活力的影响.....	86
3.2.4.3 VB ₆ 对酶的抑制类型与抑制常数.....	86
3.3 重金属离子对凡纳滨对虾 NAGase 活力的影响.....	88
3.3.1 Cu ²⁺ 对凡纳滨对虾 NAGase 活力的影响.....	88
3.3.2 Zn ²⁺ 对凡纳滨对虾 NAGase 活力的影响.....	90
3.3.3 Cd ²⁺ 对凡纳滨对虾 NAGase 活力的影响.....	91
3.3.4 Pb ²⁺ 对凡纳滨对虾 NAGase 活力的影响.....	93
3.3.5 Hg ²⁺ 对凡纳滨对虾 NAGase 活力的影响.....	94
第四章 讨论.....	97
4.1 凡纳滨对虾 NAGase 的分离纯化.....	97
4.2 健康虾与患红体病虾的壳膜和内脏 NAGase 的比较.....	97
4.3 对虾养殖常用药物对酶的影响.....	98
4.4 重金属离子对凡纳滨对虾 NAGase 活力的影响.....	100
结论.....	103
参考文献.....	104
已发表与已接受研究论文.....	112
致谢.....	113

Contents

Chinese Abstract	11
English Abstract	13
Chapter 1. Introduction	15
1.1 The Breeding Situation and General Introduction of <i>Litopenaeus vannamei</i>	15
1.1.1 Brief introduction of <i>Litopenaeus vannamei</i>	15
1.1.2 The Breeding Situation and Present Problems of <i>Litopenaeus vannamei</i>	16
1.1.2.1 The major diseases, control measures and diagnostic methods of Shrimp... 17	
1.1.2.1.1 The major diseases of Shrimp.....	17
1.1.2.1.2 Research Status of Taura Prawn.....	18
1.1.2.1.3 The prevention means of Shrimp.....	19
1.1.2.2 Overview of heavy-metal contamination.....	20
1.2 Review of Research on Chitin and Chitinase System	21
1.2.1 Review of Chitin.....	21
1.2.2 General Situation About the Study of Chitinase System.....	22
1.2.2.1 General Introduction of Chitin.....	22
1.2.2.2 Survey of Research on N-Acetyl-β-D- glucosaminidase.....	23
1.2.3 Research application of NAGase and The significance of NAGase for <i>Litopenaeus vannamei</i>	23
1.3 Significance and Contents of The Research	24
Chapter 2. Materials and Methods	26
2.1 Materials and Reagents	26
2.2 Instruments	27
2.3 Methods	27
2.3.1 Assay of Protein Concentration.....	27
2.3.2 Assay of the NAGase Activity.....	27
2.3.3 Purification of the NAGase.....	28

2.3.3.1 Purification of NAGase from the Viscera of <i>Litopenaeus vannamei</i>	28
2.3.3.2 Extraction of NAGase from <i>Litopenaeus vannamei</i> in the Different Growth Stages or Taura <i>Litopenaeus vannamei</i>	29
2.3.4 Assay of Kinetics Properties.	29
2.3.4.1 Determination of Kinetics Parameters for hydrolysis of pNP-NAG	29
2.3.4.2 Determination of the Activation Energy.	29
2.3.4.3 Determination of the Optimum pH.	30
2.3.4.4 Determination of the Optimum Temperature.	30
2.3.4.5 Determination of the pH Stability.	30
2.3.4.6 Determination of the Thermal Stability.	30
2.3.5 Effects of Some Effectors on the NAGase.	30
2.3.5.1 Effects of Metal Ions on the NAGase.	30
2.3.5.2 Effects of Organic Solvents or Pollutants on the NAGase.	30
2.3.5.3 Effects of Some Druggeries used in breeding on the NAGase.	31
2.3.5.4 Studies on kinetics of effectors on The Enzyme.	31
2.3.6 Effect of Heavy-metal ions on the activity of NAGase.	31
2.3.6.1 The setting of heavy-metal ion gradient.	31
2.3.6.2 Data processing and analysis.	32
Chapter 3. Results	33
3.1 Comparison of NAGase from Healthy and Taura <i>Litopenaeus vannamei</i>	33
3.1.1 Comparison of NAGase Activity.	33
3.1.2 Comparison of NAGase Properties.	33
3.1.2.1 Comparison of the Optimum pH.	33
3.1.2.2 Comparison of the pH Stability.	34
3.1.2.3 Comparison of the Optimum Temperature.	36
3.1.2.4 Comparison of the Thermal Stability.	37
3.1.2.5 Comparison of K_m and V_m	39
3.1.2.6 Comparison of E_a	41
3.1.3 Comparison of Effects of Some Metal Ions on NAGase from Healthy and	

Taura <i>Litopenaeus vannamei</i>	42
3.1.3.1 Comparison of Effects of Cu ²⁺ on Different NAGase.....	42
3.1.3.2 Comparison of Effects of Zn ²⁺ on Different NAGase.....	43
3.1.3.3 Comparison of Effects of Hg ²⁺ on Different NAGase.....	45
3.1.3.4 Comparison of Effects of Cd ²⁺ on Different NAGase.....	46
3.1.3.5 Comparison of Effects of Pb ²⁺ on Different NAGase.....	48
3.1.3.6 Comparison of Effects of Al ³⁺ on Different NAGase.....	49
3.1.4 Comparison of Effects of Some Organic Solvent on NAGase from Healthy and Taura <i>Litopenaeus vannamei</i>	51
3.1.4.1 Comparison of Effects of Ethanol on Different NAGase.....	51
3.1.4.2 Comparison of Effects of Formaldehyde on Different NAGase.....	52
3.1.4.3 Comparison of Effects of Phenol on Different NAGase.....	54
3.1.4.4 Comparison of Effects of Methanol on Different NAGase.....	55
3.1.4.5 Comparison of Effects of Dioxane on Different NAGase.....	57
3.1.4.6 Comparison of Effects of DMF on Different NAGase.....	58
3.1.4.7 Comparison of Effects of DMSO on Different NAGase.....	59
3.1.5 Comparison of Effects of Some Denaturants on NAGase from Healthy and Taura <i>Litopenaeus vannamei</i>	61
3.1.5.1 Comparison of Effects of NBS on Different NAGase.....	61
3.1.5.2 Comparison of Effects of SDS on Different NAGase.....	62
3.1.5.3 Comparison of Effects of Urea on Different NAGase.....	64
3.2 The Effect of Some Druggeries used in breeding on The Enzyme.....	66
3.2.1 The Effect of disinfection drug on The Enzyme.....	66
3.2.1.1 The Effect of Chlorine Family Compounds on The Enzyme.....	66
3.2.1.2 The Effect of DDAC on The Enzyme.....	70
3.2.1.3 The Effect of Glutaraldehyde on The Enzyme.....	71
3.2.2 The Effect of Some Antibiotics on The Enzyme.....	72
3.2.3 The Effect of Some Antibacterial on The Enzyme.....	74
3.2.3.1 Effect of Ciprofloxacin Hydrochloride on The Enzyme.....	74
3.2.3.2 The Inhibitory Mechanism and constanton of Norfloxacin on NAGase....	76

3.2.3.3 The Inhibitory Mechanism and constanton of Acetylsulfamethoxazole On NAGase.....	78
3.2.3.4 Effect of Sulfadiazine on The Enzyme.....	82
3.2.4 Vitamins on the Activity of NAGase.....	83
3.2.4.1 Effect of vitamin B1 and vitamin B6 on The Enzyme.....	84
3.2.4.2 Effect of vitamin C on The Enzyme.....	85
3.2.4.3 The Inhibitory Mechanism and constanton of vitamin B6 on The Enzyme..	86
3.3 Effect of Heavy-metal ions on the activity of NAGase.....	88
3.3.1 Effect of Cu ²⁺ on the activity of NAGase.....	88
3.3.2 Effect of Zn ²⁺ on the activity of NAGase.....	90
3.3.3 Effect of Cd ²⁺ on the activity of NAGase.....	91
3.3.4 Effect of Pb ²⁺ on the activity of NAGase.....	93
3.3.5 Effect of Hg ²⁺ on the activity of NAGase.....	94
Chapter 4. Discussion.....	97
4.1 Purification of NAGase.....	97
4.2 Comparison of NAGase from Healthy and Taura Prawn.....	97
4.3 Effect of Some Druggeries used in breeding on The Enzyme.....	98
4.4 Effect of Heavy-metal ions on the activity of NAGase.....	100
Conclusions.....	103
References.....	104
Papers.....	112
Acknowledgements.....	113

摘 要

凡纳滨对虾(*Litopenaeus vannamei*)是全世界三大养殖对虾中单位产量最高的虾种。N-乙酰-β-D-氨基葡萄糖苷酶(N-Acetyl-β-D-glucosaminidase, 简称NAGase, EC. 3.2.1.52)在对虾的蜕壳发育和营养代谢中发挥着重要作用。因此,研究凡纳滨对虾在患病过程的酶学变化,探讨环境污染物、饲料添加剂、水产养殖常用药物等对NAGase活力的影响与调控,以及对虾活体急毒性试验的开展,探究重金属离子对凡纳滨对虾NAGase活力的影响,将有利于对虾养殖业发展,为对虾养殖水环境污染监测提供更加充分、直观的科学依据,并填补国内外在这方面的研究空白。本文以凡纳滨对虾壳膜与内脏所提NAGase为对象,展开以下几方面的研究。

(1) 跟踪考察分析健康和患红体病的凡纳滨对虾壳膜与内脏NAGase的活力和性质的差异。测得健康对虾壳膜NAGase的活力为34.80 U/mg,内脏NAGase的活力为35.34 U/mg;而患红体病对虾壳膜NAGase的活力为38.32 U/mg,内脏NAGase的活力为20.02 U/mg。结果表明:两种来源对虾的NAGase活力、基本酶学性质等均存在差异。对虾患红体病后,壳膜与内脏NAGase的催化反应动力学常数 K_m 和 V_m 值、活化能均较高,但其最适温度较低,pH稳定性及热稳定性较差。同时,对虾患病前后,壳膜与内脏来源的NAGase对外界各影响因子(Hg^{2+} 、 Zn^{2+} 、 Cu^{2+} 、 Cd^{2+} 、 Pb^{2+} 、 Al^{3+} 等重金属离子污染物;乙醇、甲醛、苯酚、甲醇、二氧六环、DMF、DMSO等有机污染;脲、NBS、SDS等常用化学修饰剂及变性剂)的敏感性也发生了变化。

(2) 养殖水体常用消毒药物中,次氯酸钠、三氯异氰尿酸、季铵盐对凡纳滨对虾壳膜与内脏来源的NAGase的活力有不同程度的影响。同时,次氯酸钠、三氯异氰尿酸对两种来源的酶的抑制为不可逆过程。青霉素钾、链霉素、庆大霉素、卡那霉素等对壳膜与内脏来源的NAGase活力基本上没有影响;养殖常用的内服、外用抗菌药物中,盐酸环丙沙星对两种来源的酶有激活作用,而诺氟沙星和磺胺甲噁唑对酶活力则有不同程度的抑制作用。磺胺甲噁唑对壳膜NAGase表现为混合型可逆抑制,对内脏来源的NAGase表现为非竞争性抑制;诺氟沙星对内脏来源的NAGase为混合型可逆抑制。考察几种养殖常用维生素对内脏NAGase活力的影响,其中 VB_{12} 、烟酸、核黄素等对酶活力基本上没有影响;而

VB₁、VB₆、抗坏血酸等对该酶活力均有不同程度的抑制作用，进一步研究了 VB₆ 的抑制作用动力学，其对酶的抑制作用为非竞争性可逆抑制。

(3) 对凡纳滨对虾进行养殖试验，研究重金属离子对对虾 NAGase 活力影响，在不同时间取样并考察 Cu²⁺、Zn²⁺、Cd²⁺、Pb²⁺、Hg²⁺等重金属离子对凡纳滨对虾壳膜及内脏 NAGase 活力的影响。结果显示 5 种重金属离子低浓度组在短时间内对凡纳滨对虾壳膜与内脏的 NAGase 活力没有显著影响，48h 后随作用时间的延长，重金属离子使两种来源的 NAGase 活力均逐渐降低，表现为显著性抑制的剂量效应关系。

关键词：凡纳滨对虾；N-乙酰-β-D-氨基葡萄糖苷酶；性质；活力调控；动力学

Abstract

The production per unit of *Litopenaeus vannamei* tops among three major prawns in the world. And it is known that N-Acetyl-β-D-glucosaminidase (NAGase EC. 3.2.1.52) plays a pivotal role in molting and nutritious metabolism of prawns. Hence, our study of enzymatic changes of prawns when sick, the effects of environmental pollutants, forage addition and common drugs used for aquatic breeding on the activities of NAGase, along with the study of acute toxic assays on prawn living bodies and the effects of heavy metal ions on activity of NAGase of prawns will benefit the prawn breeding industry and provide a more sufficient and direct scientific basis for monitoring the pollution in aquatic environment for culturing the prawn. Meanwhile, our study fulfills the blank in this field both domestically and internationally. Our study focuses on the NAGase extracted from *Litopenaeus vannamei* and falls into three categories:

(1) Study of differences of activities and properties of NAGase in prawns between health ones and the ones with “red body disease (RBD)”. Our results show that the activities of NAGase in shell membrane and viscera of healthy prawns are 34.80 U/mg and 35.34 U/mg, respectively; while the activities of NAGase in shell membrane and viscera of prawns with RBD are 38.32 U /mg and 20.02 U/mg, respectively. This illustrate that there are differences between healthy prawns and the ones with RBD in activity and basic enzymatic properties of NAGase. Although catalytic reaction kinetic constant K_m and V_m value and activity energy of NAGase from the shell membrane and viscera of prawns with RBD are higher, the optimal temperature of NAGase is lower; also pH and thermal stabilities of NAGase are worse. At the same time, the sensitivity of NAGase changes between healthy prawns and prawns with RBD to outside factors, including heavy metal ions like Hg^{2+} , Zn^{2+} , Cu^{2+} , Cd^{2+} , Pb^{2+} , Al^{3+} ; organic pollutants like ethanol, formaldehyde, phenol, methanol, dioxane, DMF and DMSO; common chemical dressing agent and denaturant like urea, NBS and SDS.

(2) Study of different effects of common antidote for aquatic bodies, such as sodium hypochlorite, symclosene and quaternary ammonium on the activity of NAGase from shell membrane and viscera of *Litopenaeus vannamei*. Meanwhile, the inhibitions of sodium hypochlorite and symclosene to these two different enzymes are irreversible. Moreover, our results show that benzylpenicillin potassium, streptomycin, gentamicin and kanamycin have no effect on the activities of these two kinds of NAGase. Our results also show that among common antibiotics, ciprofloxacin activates these two kinds of NAGase while norfloxacin and sulfalene inhibit them. Sulfalene shows mixed reversible inhibition on NAGase from shell membrane while noncompetitive inhibition on NAGase from viscera; norfloxacin shows mixed reversible inhibition on NAGase from viscera. We also study the effects of several common vitamins on the activity of NAGase extracted from viscera. Our data illustrate that VB₁₂, niacin and lactoflavin have no significant effect on the enzyme activity while VB₁, VB₆ and ascorbic acid inhibit it in distinct degrees. Further kinetic study shows that the inhibition of VB₆ on the enzyme is noncompetitive.

(3) Study of culture conditions for *Litopenaeus vannamei*, and different effects of heavy metal ions on NAGase activities. We study how different metal ions such as Cu²⁺, Zn²⁺, Cd²⁺, Pb²⁺, Hg²⁺ affect the activity of NAGase extracted from shell membrane and viscera of *Litopenaeus vannamei*. Our results show that no significant change in the activity of NAGase extracted from shell membrane and viscera of *Litopenaeus vannamei* treated with these five metal ions in short time. Nevertheless, the activities of these two NAGase decrease after 48 hours treatment with metal ions, which indicates a significant dose-dependent inhibition.

Key words: *Litopenaeus vannamei*; β-N-Acetyl-D-glucosaminidase; properties; activity control; kinetics

第一章 前言

1.1 凡纳滨对虾概况及养殖

凡纳滨对虾 (*Litopenaeus vannamei*) 又称南美白对虾、万氏对虾、白脚虾、白腿对虾, 分类上隶属于节肢动物门 (Arthropoda)、甲壳纲 (Crustacea)、十足目 (Decapoda)、游泳亚目 (Natantia)、对虾科 (Penaeidae)、对虾属 (*Penaeus*)、*LitoPenaeus* 亚属^[1]。原产于中、南美洲太平洋沿岸的温暖水域, 以厄瓜多尔沿岸分布最为集中, 与斑节对虾、中国对虾并列为世界对虾养殖的三大品种, 是集约化高产养殖的优良品种^[2]。具有壳薄、肉厚、生长快、群体增长均匀、抗逆性强、耐盐性广、营养要求低、食性广、出肉率高、肉味鲜美、离水存活时间长以及经济价值高等优点^[3~6]。我国于 1988 年由张伟权教授引进, 1994 年批量育苗成功^[7]。现已在全国沿海养殖, 由于其耐低盐度, 许多内陆地区也试养成功, 我国年产量已达 12 万吨^[7,8]。

1.1.1 凡纳滨对虾简介

凡纳滨对虾外形与中国明对虾 *Fenneropenaeus chinensis* 酷似, 成体最长可达 23cm, 正常体色为青蓝色或浅青灰色, 全身不具斑纹; 额角稍向下弯, 额角尖端的长度不超过第一触角柄的第二节, 其齿式为 59/24; 头胸甲短, 与腹部长度之比为 1:3; 体长而侧高, 略呈梭形; 额角侧沟短, 止于胃上刺下方; 头胸甲具肝刺和鳃角刺; 第一触角具双鞭, 内鞭较外鞭纤细, 长度大致相等, 约为第一触角柄长度的 1/3; 第 1-3 对步足的上肢十分发达, 第 4-5 对步足无上肢, 第 5 对步足具锥形外肢; 尾节具中央沟, 但不具缘侧刺^[1]。该虾广泛分布于太平洋沿岸水域秘鲁北部至墨西哥桑诺拉一带^[9]。

凡纳滨对虾属杂食性种类, 偏动物性食性。自然水体中, 在幼虾期, 主要以水生昆虫幼体、小型甲壳类、水生蠕虫、动物尸体、有机碎屑等为食; 成虾期食物组成多样。对饲料的固化率要求较高, 但对动物性饵料的需求并不十分严格, 只要饵料成分组成中蛋白质的比率占 25% 以上, 即可正常生长^[10~13]。繁殖期间, 尤其是性腺发育中、后期, 摄食量明显增大。凡纳滨对虾忍受的高、低温极限为 41℃ 和 4℃, 生存的水温为 6-39℃, 在 18-35℃ 水温范围内均可摄食和生长, 而在 24-33℃ 摄食和生长较好, 且随温度的升高, 凡纳滨对虾的摄食和生长增强。30-33℃ 是凡纳滨对虾生长和摄食的最适水温, 在此温度下摄食和生长均可达到

Degree papers are in the "[Xiamen University Electronic Theses and Dissertations Database](#)". Full texts are available in the following ways:

1. If your library is a CALIS member libraries, please log on <http://etd.calis.edu.cn/> and submit requests online, or consult the interlibrary loan department in your library.
2. For users of non-CALIS member libraries, please mail to etd@xmu.edu.cn for delivery details.

厦门大学博硕士论文摘要库