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Crustacean Endocrinology: Intriguing Towards Quality Protein Production

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Abstract

Present World in dearth of nutritious food, especially proteinaceous food forever growing human population. Alternatives are in search in producing more high quality protein food in a short time with available resources. The crustacean aquaculture is one of the important agricultural fields in producing high quality proteinaceous food, but it is having its own limitations to produce more amount of protein food. However, manipulation of endocrine system is one of the best ways to increase crustacean protein food. This article reviews the possible ways of crustacean endocrine manipulations to promote the growth to increase protein productivity in crustacean aquaculture industry.

Introduction

Malnutrition is the major problem in the developed, developing and third World countries where the people's diet does lacking adequate calories and protein for maintenance and growth. Supplementation of nutritious food to everyone in the World is a big task ahead, to achieve this more amount of quality food, especially protein should be produced with the available resources. Agriculture is the main source of producing protein of which aquaculture plays an important role in producing quality protein. Both finfish and shellfish come under aquaculture. Finfish culture is much better in producing protein than shellfish culture. In shellfish, crustaceans are most important animals to produce quality protein which has high value Worldwide.

Many studies are under taken to improve the crustacean protein in the past. One of the classical method followed to increase the growth in crustaceans is by eyestalk ablation unilaterally or bilaterally [1-6]. Induction of precocious molting has also been well documented in the spider crab, *Libinia emarginata* [7], in the freshwater crab *Oziothelphusa senex senex* [8] and the freshwater prawn, *M. rosenbergii* after eyestalk ablation [9]. Though eyestalk ablation induces the growth and reproduction in cultured species, but has its own limitations like loss of hemolymph by cautery, mortality in the ablated animals and hormonal imbalance since an array of hormones synthesized and secreted from eyestalk are removed [10-12].

Table 1: CHH family peptides and their overlapping biological activities.

S. No.	Chh-Family Peptide	Specific Activity	Overlapping Activity	References
1	CHH	Glucose metabolism and Osmoregulation	Molting and Reproduction	Jeon et al. [42], Webster et al. [57]
2	MIH	Molting	Reproduction and Glucose metabolism	Reddy et al. [3], Zmora et al. [58], Luo et al. [48]
3	MOIH	Molting and Reproduction	Glucose metabolism	Wainwright et al. [25], Lu et al. [47], Nagaraju et al. [50], Reddy and Reddy [2,3]
4	GIH/VIH	Reproduction	Glucose metabolism and Molting	De Kleijn and Van Herp [41], Kang et al. [43]
5	RPCH	Exoskeleton pigmentation	Ovarian maturation and molting	Kulkarni et al. [30], Sarojini et al. [19], Swetha et al. [18]

Eyestalk in crustaceans is a reserve for many hormones regulates several physiological functions comprising growth and reproduction. An array of hormones released from crustacean eyestalk includes crustacean hyperglycemic hormone (CHH), molt-inhibiting hormone (MIH), mandibular organ-inhibiting hormone (MOIH) and gonad/vitellogenesis-inhibiting hormone (VIH) besides other hormones and neurotransmitters (see reviews [2,13-16]. These eyestalk neuropeptides are collectively called as CHH-family peptides since they share the functional similarity and show multiple biological functions (Table 1).

Table 2: The synthesizing, storage and releasing site, nature and functionality of various crustacean endocrine hormones involved in the regulation of growth.

S.No.	Hormone	Synthesizing site	Storage site	Releasing site	Nature	Function	References
1	CHH	Eyestalk ganglion	Sinus gland	Hemolymph	Neuropeptide	Glucose and glycogen metabolism, Osmoregulation, Molting and Reproduction	Keller and Sedlmeier [44], Santhos et al. [53]
2	MIH	Eyestalk ganglion	Sinus gland	Hemolymph	Neuropeptide	Molting, Reproduction and Glucose metabolism	Chang [39] Chang and Mykles [38], Watson et al. [56]
3	MOIH	Eyestalk ganglion	Sinus gland	Hemolymph	Neuropeptide	Molting, Reproduction and Glucose metabolism	Tamone et al. [54], Borst et al. [34], Reddy et al. [4], Nagaraju et al. [50]
4	GIH/VIH	Eyestalk ganglion	Sinus gland	Hemolymph	Neuropeptide	Reproduction and Molting	Quackenbush, [52], Aguilar et al. [32], De Kleijn et al. [41]
5	Ecdysteroids	Y-organ	Y-organ	Hemolymph	Steroid	Molting and Reproduction	Chung, [20] Nakatsuji et al. [51]
6	MF	MO	MO	Hemolymph	Terpenoid	Molting and Reproduction	Nagaraju et al. [51] Suneetha et al. [27] Hemalatha et al. [28]
7	Seratonin	Eyestalk ganglion	Sinus gland	Hemolymph	Hydoxy tryptamine	Neurotransmission and Molting	Sainath and Reddy [29]
8	Leucine-enkephalin	Eyestalk ganglion	Sinus gland	Hemolymph	Tripeptide	Glucose metabolism and molting	Kishori and Reddy [45], Nagabhushanam et al. [19]

Besides eyestalk hormones, the sesquiterpenoid hormone methyl farnesoate (MF), various types of ecdysteroid hormones and many other neurotransmitters show effects on growth (see reviews [14,17,18]. The synthesizing, storage and releasing site, nature and functionality of these molecules are presented in (Table 2). This review emphasizes, an over view of crustacean endocrine hormones and their manipulations towards better growth and quality protein production.

CHH-family neuro peptide hormones

The X-organ sinus gland complex located in the eyestalks synthesizes and secrets CHH-family neuro peptides. The main feature of CHH-family peptides is structural similarity. Due to this they execute multiple functions and shows overlapping biological functions [3]. MIH of these group show inhibitory function on growth and the other peptides also show inhibition as a subsidiary function (Table 1). Manipulation of MIH expression, a way to nullify the inhibitory function of MIH on growth. Recent studies are focused on manipulating this hormone either by removal of eyestalk a classical method bearing several disadvantages and an alternatively by suppressing its activity through RNAi mechanisms [4]. Since most of the CHH-family peptides are having dual biological functions and exhibits inhibitory action on molting of crustaceans (Figure 1), the better way to increase growth is by gene knockout studies. Though the success rate of gene knockout studies is very less, more studies to stabilize these experiments are essentially done by the researchers.

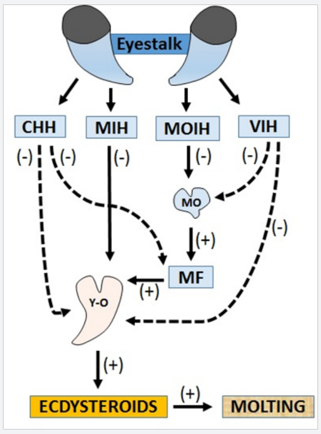

Figure 1: Biological functions of CHH-family neuropeptides. CHH: Crustacean Hyperglycemic Hormone; MIH: Molt-inhibiting Hormone; MOIH: Mandibular Organ-inhibiting Hormone; VIH: Vitellogenesis-inhibiting Hormone; MF: Methyl Farnesoate; MO: Mandibular Organ; Y-O: Y-organ; '+': Induction; '-': Inhibition.

Ecdysteroids

The Y-organ of crustaceans is responsible to produce a group of steroid hormones collectively called as ecdysteroids. The primary function of ecdysteroids in crustaceans is promoting growth [13,14,19]. In another words, increased ecdysteroid levels promotes animal from intermolt to molt (ecdysis) irrespec-

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tive of other factors. Since they coordinate molting process they can also be called as molting hormones and the Y-organ as molting gland. These hormones along with another hormone methyl farnesoate promote molting thereby increases the weight of the animal. Many studies are contemplated on ecdysteroid induced growth mostly by injecting these molecules in vivo and in vitro incubation studies [20].

Since ecdysteroid comes under family steroids, instead of injecting these molecules directly into the crustacean for increasing growth, it is better to increase the steroidogenic pathway which in turn increases ecdysterodiogenesis in Y-organs thereby growth of the animal. The Probiotic approach is one of the best ways to increase the ecdysterodiogenesis. Probiotics are combination of food material with live microorganisms that promotes the growth of beneficial microbes in the gut. The most commonly used microbes belong to two bacterial divisions, the *Firmicutes* (e.g. *Bacillus* spp., *Lactobacillus* spp., *Lactococcus* spp., *Carnobacterium* spp. etc.) and the *Gammaproteobacteria* (e.g. *Vibrio* spp., *Pseudomonas* spp., *Shewanella* spp. etc.), while yeasts remain rarely studied [21]. These probiotics changes the gut microbiome of a crustacean with increased digestive capacity and assimilation of digested components into the hemolymph thereby activated metabolism keeps the animal healthy. An active and healthy animal molt faster and attains growth in a short time. Nevertheless, beyond these considerations, especially in Asia Probiotic applications have been a practical and commercial reality in shrimp farming for more than 15 years. In China, more than 100 companies are producing different varieties of probiotics for aquaculture industry [22]. However, in aquatic cultured species the most important factor that needs to be considered is how animals raised and fed which influence the autochthonous and allochthonous microbial communities [23].

Probiotics to produce substrates to initiate ecdysteroidogenesis are appropriate to induce molting in crustaceans. This may be the best way to attain growth in crustaceans, where the lacuna is to proceed further in producing high quality and greater volume crustacean protein.

Methyl farnesoate

The sesquiterpenoid hormone synthesized and secreted from a pair of glands called mandibular organs (MOs) is named as methyl farnesoate (MF). MOs are under the control of eyestalk hormone MOIH, which inhibits the MF synthesis. MF involved in both growth and reproduction and promotes both process [3,4,8,24-28]. The roles of MF on molting were well established in variety of crustaceans and are focused on injecting the MF directly into the animal and studied its effects on growth and reproduction in the laboratory. MF is potential inducer of growth in crustaceans [8]. Since it is not practically possible to inject each animal with MF, the alternative to increase MF levels is by supplementation through the food (Probiotic approach) or by suppressing the action of MOIH by RNAi silencing mechanism. Both the ways are not yet clearly established in crustaceans and is open for crustacean scientists.

Other molecules

Many other molecules secreted in or coming from the environment are capable to induce growth in crustaceans. The best examples are biogenic amines and opioid peptides. They synthesized in crustaceans and influences the growth of the animal. The biogenic amines serotonin and melatonin are proved to be involved in promoting growth in crustaceans [29]. The opioid peptides leucine encephalin and methionine encephalin produced from the crustacean eyestalk also play a role in molt regulation. Especially leucine enkephalin involved in promoting growth in crab *Oziothelphusa senex senex* [30]. Besides this temperature of the medium and photoperiod also promote molting in some crustaceans [31-35]. However, the role of biogenic amines, opioid peptides and external factors are still under dearth of literature, need more attention of researchers [36-45].

Conclusion

It is essential to emphasis that food scarcity, in particular protein is the biggest hurdle standpoint in the World. It is essential to look for alternatives to produce more food within the available resources [46-51]. Crustacean aquaculture produces, high quality and delicious protein, but has its own limitations to produce added amount of protein. To produce crustacean protein, further alternatives are in search. This review focused on the potential lacunas in crustacean molting research. Such as

A. Controlling of molt inhibitory gene expression by means of RNAi technique

B. Growth increase by using appropriate Probiotic and Probiotics which can induce ecdysterodiogenesis in Y-organs and MF synthesis in MOs respectively

C. Focused studies desirable on biogenic amines, options and external factors [52-58].

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