



Feeding rate and sexes affect gonad growth of donkey ear abalone *Haliotis asinina* Linnaeus, 1758

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Abstract. Aquaculture of donkey ear abalone *Haliotis asinina* has recently expanded to meet the growing market demands. However, the low meat recovery relative to gonad size upon harvest is an issue that concerns processors and aquaculturists. Manipulation of feeding rate is an important aspect in aquaculture to attain high feed conversion efficiency while maximizing the full growth potential of the stock. Influence of feed rate on growth of aquatic vertebrates are well studied but effects of feed rate on the development of gonads relative to body size and sex of commercially important invertebrate, *Haliotis asinina* has not been fully investigated to date. The present experiment evaluated the influence of feeding rate relative to sexes and the gonad development of abalone *H. asinina*. The experiment was ran following a 2x2 factorial design with equal groups of male and female abalones subjected to two feeding regimens with one group receiving feed at a rate of 10% of body weight and the other group maintained with an ad libitum feeding regimen. Results showed that at 15 days of culture, gonad bulk index was influenced with the interaction of feeding rate and sex. Females given the ad libitum feeding regimen were found to have the highest gonad bulk index. However at 30 days of culture, feeding rate was found as the sole factor influencing gonad growth. Regardless of sex, those fed with the ad libitum has a higher gonad bulk index. Collectively, these present data suggest that 10% feeding rate is ideal to reduce the meat to gonad ratio of grown abalone. This feeding scheme could reduce the growth allocation to gonad and more yield of body meat could be recovered from this species of *H. asinina*.

Key Words: Gastropod, growth, ad libitum, aquaculture, gonad bulk index.

Introduction. The donkey ear abalone *Haliotis asinina* is an economically important marine gastropod inhabiting the rocky coastal reef zones of the Philippines. Currently, the increase in market demand has led to the increase in the prices of abalone products indicating shortage in production coming from the fisheries harvest and from aquaculture. Aquaculture of *H. asinina* in the Philippines is well-established since the wild population has dwindled due to unregulated exploitation to satisfy the growing demand of the export market (Ungson 2003). *H. asinina* is priced as an aquaculture commodity since it exhibits the ability to mature and spawn throughout the year, fast growth rates, and high survival during grow-out in both land- and sea-based culture systems (Gallardo & Salayo 2003). However, since this abalone matures at an early period, the large bulk of the gonad is considered a problem in selling this economically important marine gastropod. High gonad to body meat ratio lowers the marketability and value of this abalone since foot muscles are the only part collected for processing, packaging and marketing.

Like any cultured invertebrates, energy intake in the form of food is considered as influencing factor in the development of gonad size and body muscle growth. In tropical abalone like *H. asinina*, it has been documented that sexual maturation could be attained by feeding with its natural food – the red algae *Gracilariopsis heteroclada* (Fermin 2001). Although studies on the culture of this abalone species with respect to the type of feed and nutrient requirements have been reported, studies designed on the evaluation of feeding rate and sexes on the gonad growth of this species has not yet undertaken to

date. The present study aimed to evaluate the influence of feeding rate and sexes on the gonad bulk index of cultured *H. asinina*. Gonad index has been widely used in assessing the reproductive status of invertebrates that usually involves a measure of the mass of the gonad of an animal relative to its total body mass (Gurney & Mundy 2004). The results of this study will be helpful in determining what sexes and feeding rate would be ideal to produce a high marketable biomass of cultured *H. asinina*.

Material and Method. The study was conducted along Bongao Channel at the back of the College of Fisheries, Mindanao State University, Tawi-tawi, Philippines. This site is ideal for abalone culture since water circulation due to a constant mild current ensures good water quality. The study lasted for 30 days. Experimental units were arranged following a 2 x 2 factorial in randomized complete block design (RCBD) with four treatments in triplicate. There were two factors tested and each factor has two levels. The first factor is the feeding rate consisting of groups fed with 10% of their body weight the other group fed with ad libitum feeding rate. The second factor is the sexes of the experimental animals with one group all male and the other groups all females.

Experimental units. Each experimental block consists of three units of circular basket, made of amazon screen (100 cm height x 80 cm diameter). This net basket was provided with opening at the top and cover fastened with rope to secure the plastic mesh tray arranged inside. The circular baskets were tied in a bamboo spars tied to the concrete pillars along the coralline area. Each basket contained four units of plastic mesh tray (12 x 6 x 6 inches) for a total of 12 trays used as experimental units in the experiment.

Experimental organisms. The *H. asinina* were purchased from abalone gatherers within the island of Bongao Tawi-tawi, Philippines. Abalones with initial body weight of 50 g were used in the study following the manual procedure of SEAFDEC (2007). Strong and healthy abalones with a shell free from deformities, damage and fouling agents were selected. Subjects were placed in a pail and brought to the study site. Randomly, the abalones were put in plastic mesh trays and arranged inside a circular basket. The circular baskets were hanged in a bamboo pole in the area prepared near the rock enclosure. The abalones were fed with *G. heteroclada* at a rate of 10% of the body weight and ad libitum. Feeding and checking of gonad index were done every sampling day. After every three days, the feed left in 10% ABW were measured. However, in abalone with ad libitum feeding, trays were added with fresh seaweeds without measuring the left over. Circular baskets and plastic mesh trays were cleaned every three days by brushing and flushing with seawater without touching the organisms to avoid introduction of stress to the animals.

Gonad bulk index (GBI). Sampling was done every 15 days to analyze the influence of the factors on the gonad size. All experimental animals were checked for its gonad index. Attached abalones were gently detached from the tanks wall using PVC spatula. Determining the GBI was done by holding the shell of the abalone of both ends and exposing the gonads for measurement as described in the methods of SEAFDEC (2007) and Newman (1967). The water temperature (26-27°C), salinity (35-38 ppt), pH (7-8.2) and oxygen (>5ppm) levels were maintained to the optimum levels throughout the experimental run (Capinpin Jr et al 1998; SEAFDEC 2007).

Statistical analysis. The experimental data were analyzed using two-way analysis of variance (Two-way ANOVA) and significant differences among treatments were determined using orthogonal contrast. Data were presented in means \pm standard deviation (SD) and α was set at 0.05 level of significance.

Results and Discussion. Following 15 days of culture, results showed a direct interactive influence of sex and feeding rate on gonad size relative to the whole body size. Gonad bulk index was basically affected by feeding rate with ad libitum treatment exhibited higher GBI regardless of the sexes. However, significantly higher GBI was

obtained in females fed ad libitum and females that received the 10% dietary treatment were observed to exhibit the lowest GBI among the treatment groups. GBI of males were observed to be not affected by the dietary treatments (Table 1).

Table 1

Effect of feeding rate and sexes on the gonad development of *Haliotis asinina* during the 15 days of culture

<i>Factor</i>		<i>Gonad index (GBI)</i>
<i>Sexes</i>	<i>Feeding rate</i>	
Female	10%	14.82 ± 3.29 ^b
	Ad libitum	28.11 ± 3.29 ^a
Male	10%	22.41 ± 3.29 ^{ab}
	Ad libitum	24.41 ± 6.57 ^{ab}
ANOVA (<i>P</i> value)		
Sexes		0.715
Feeding rate		0.029
Interaction		0.029

Presented data are means ± SD of triplicate groups.

Means having the same superscript letter on the same column are not significant ($p > 0.05$).

On the 30th day of culture, results showed that gonad development was significantly affected by feeding rate. At this period, the manifestation of feeding rate on gonad development has already manifested. Results suggest that regardless of sexes whether male or female, those that received the ad libitum dietary treatment exhibited the highest GBI (Table 2).

Table 2

Effect of feeding rate and sexes on the gonad development of *Haliotis asinina* during the 30 days of cage culture

Index	<i>P</i> value			<i>Sexes</i>		<i>Feeding rate</i>	
	<i>Sexes</i>	<i>Feed rate</i>	<i>Interaction</i>	Female	Male	10%	Ad libitum
GBI	0.593	0.003	0.593	34.77±8.54	33.22±7.00	28.10±2.94 ^b	39.89±5.61 ^a

GBI - Gonad Bulk Index; Presented data are means ± SD, n=3; Means having the same superscript letter on the same row for each factor are not significant ($p > 0.05$).

H. asinina is a priced marine gastropod in Southeast Asia. The fast growth and short period of attainment of reproductive maturity makes this species ideal for aquaculture. However, the large gonad size relative to the overall marketable foot muscle is a concern among growers and processors. Though this problem has existed since the culture of *H. asinina* has been developed, this biological aspect is not yet well investigated until now. The current data presented on this work, to our knowledge is the first time to be done in this species of abalone. The present findings suggest that at earlier part of the culture the interaction of feeding rate and sexes has a significant contribution to the gonad development in terms of GBI. At this early period of growth, it appears that the females GBI is highest when fed with add libitum diets while males GBI is not influenced by diets. Furthermore, this data suggest that female gonad grows faster than the male gonad and is highly affected by the nutrient and caloric intake. The present results agree well with

the findings of Setyono (2007) indicating that well fed mature female abalone would accumulate and develop ripe oocyte continually that would result to a higher GBI as influenced by dietary intake. Moreover, this earlier work has able to document the influence of ad libitum dietary regimen to successful spawning of mature *H. asinina*. Tropical abalones are known to reach sexual maturity at a short period of time as compared to the temperate species. The female egg that is generally larger in size continually grows as sexual maturity commences. This explains the obvious and significant difference in GBI of female *H. asinina* than the males in response to the ad libitum dietary treatment. The present findings also support the work of Maliao et al (2004) showing that abalone in wild population maintains a number of individuals of each sex with similar stages of gonad development. In most cases, females exhibit larger gonad size than males. Further, it was also observed in earlier works that male *H. asinina* are partial spawners as shown by histological observation (Capinpin Jr. et al 1998). Male abalone is known for it to easily release spermatocytes due to its fine size and this could be the reason why males fed with ad libitum develop less GBI as compared to females as observed in the present study.

As the culture progresses, data suggest that at day 30 regardless of sexes, significant influence of feeding rate on gonad growth has manifested. At this period, no clear differences in GBI of both sexes could be observed. In contrast to the condition of the first sampling wherein the male has less GBI, at day 30 both sexes exhibited similar GBI. The difference in GBI on the 15th day could only be attributed to the fast initial growth of the female gonad due to oogenesis but at this period, the female gonad has reached its maturation peak and at the same time the male gonad has also reached its growth peak resulting to a similar GBI in both sexes.

In most invertebrates studied, constant access to food could be associated with faster maturation of ovarian cells. The presence and abundance of food has been reported as a triggering factor in the initiation of gametogenesis and vitellogenesis in marine gastropods (Capinpin Jr. et al 1998; Shepherd & Laws 1974). These earlier findings corroborates well with the findings of the present study showing the strong influence of food availability and abundance on the growth of the gonad. To ensure that abundant food would be available for the larvae to survive after hatching could be the reason for the strong correlation of food abundance and ovarian maturation in invertebrates (Shepherd & Laws 1974). Also, the presence of bioactive compounds in the feed material specifically the presence of arachidonic acid and polyunsaturated fatty acids in red seaweed, *G. heteroclada*, used as feed for the abalone may result to the significant influence of diet on gonad growth and maturation. ARA is a major precursor of prostaglandins, which influence reproduction in molluscs (Daume 2007) and the significant growth of abalone gonad fed the ad libitum dietary regimen could be attributed to this bioactive nutrient. Although for hatchery and breeding aspects of abalone culture, fast maturation and large gonad may indicate good larval production but in terms of industrial scale grow out system, large gonad size is an indication of less quality product and that could be translated to a lower profit.

Conclusions. The present findings suggest that dietary allocation could influence the GBI of both male and female abalones. It is concluded that ad libitum dietary regimen could increase GBI and the ideal dietary regimen to attain better production yield of cultured abalone with less GBI is feeding the abalone diet that is about 10 percent (10%) of its body weight. This amount is not yet the optimum and this aspect needs further investigation to come up with abalone production with optimum body to gonad ratio to ensure profitability of this economic venture.

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