Growth of market-size abalone (Haliotis midae) fed kelp (Ecklonia maxima) versus a low-protein commercial feed

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Abstract

The growth of grow-out abalone fed on kelp, with ca. 10 % dry weight protein content, was compared with that of those fed a new ,ca. 26 % protein, commercial feed in a flow-through system on a South African west coast commercial abalone farm. While both feeds produced similar gains in shell length (45.220 µm.day^{-1} for kelp, 46.839 µm.day^{-1} for commercial feed), the latter significantly outperformed kelp in terms of weight gain (0.266 % body weight.day^{-1} for commercial feed; 0.257 % body weight.day^{-1} for kelp). This low-protein commercial feed may prove to be of considerable benefit as substitute for the kelp plus high-protein feed sometimes used for abalone, because it has most of the benefits of the two feeds, but none of their apparent disadvantages.

Keywords: formulated feed, growth, Haliotis midae, kelp, protein content, South Africa.

Introduction

The growing South African abalone farming industry depends on a steady supply of feed resources (Troell et al. 2006). Based on feed sales and seaweed harvest data, in 2006 approximately half the abalone feed requirements were kelp and half were commercial formulated feed (P Britz, South African Institute for Aquatic Biodiversity, pers. comm.). However, kelp is low in protein (ca. 10% protein content on a dry weight basis) (Hahn 1989, Robertson-Andersson 2003, Troell et al. 2006) and, till recently, was approaching the limits of sustainable harvesting, particularly in those kelp concession areas with high abalone farm concentrations (Anderson et al. 2003, 2006, Rothman et al. 2006). These two factors partly motivated the development of more nutritionally complete, high-protein formulated feeds which are now widely used on commercial abalone farms either as a complete diet or as a supplement to kelp (Sales and Britz 2001, Bautista-Teruel et al. 2003, Sales and Janssens 2004, Troell et al. 2006).

The commercially available formulated Abfeed® (Marifeed Pty Ltd, South Africa) is currently the most widely used commercial abalone feed in South Africa (Troell et al. 2006) with a high protein (34%) version (Abfeed®-S34) being the first to be tested. In general, commercially-grown abalone have been found to grow best on Abfeed®-S34, at least until they reach 50mm in shell length, with most farmers now using it in the early stages of development (Troell et al. 2006). Once abalone reach 50mm in shell length, they are fed either kelp, a combination of kelp and Abfeed, or solely Abfeed (Troell et al. 2006, Britz pers. comm.). There are various reasons for this. First, although kelp has a higher food conversion ratio (FCR) (Hahn 1989, Britz 1996) and thus a lower feed conversion efficiency (FCE), it is cheaper than Abfeed. Second, once abalone had reached 50mm in shell length their high-protein formulated feed was associated with a higher incidence of sabellid worm infestations, particularly on farms with poor water quality and tank hygiene, because the worms feed on the nutrient-rich abalone faeces (Simon et al. 2004, Troell et al. 2006). Third, at higher temperatures and relatively lower water flow rates, the negative impacts of Abfeed on water quality are greater than those of kelp (Jones and Britz 2006). Fourth, kelp is relatively high in ash content (25% on a dry-weight basis) and thus rich in minerals, and this often results in higher shell growth rates in larger abalone (Troell et al. 2006). These factors motivated the development of lower protein commercial feeds that included kelp as a feeding stimulant. Currently, Abfeed®-S34 is generally used for smaller abalone, <50mm in shell length, while lower protein commercial feeds are used for larger abalone, with shell lengths >50mm.

There is a lack of information concerning alternative formulated feeds for grow-out abalone (i.e. with shell lengths >20mm) cultured in various systems. While unpublished data exists (e.g. Jones and Britz 2006, Hattingh 2006), there are no published accounts comparing results obtained with low-protein commercial feeds. This research therefore aimed to compare the growth of grow-out abalone fed kelp with that of those fed low-protein commercial Feed A in a flow-through system on a commercial abalone farm situated on the South African west coast.

Materials and Methods

Experimental system

The research was conducted at the Jacobsbaai Sea Products (JSP), Western Cape, South Africa, commercial abalone farm (17° 53' 12.5" E, 32° 58' 2.5" S). Moderately aerated seawater flowing at 850-1300 $L.h^{-1}$ was supplied at 13.8±0.76°C in flow-through concrete production tanks (5500 x 1300 x 550mm length, width and depth, respectively). The flow direction in each tank was alternated weekly to compensate for end effects. Abalone were grown in culture baskets (800 x 570 x 250mm; length, width, depth) subdivided with vertically-orientated feeding plates to increase the surface area, as well as a horizontal feeder plate (600 x 380mm) positioned centrally above the vertical plates. This design provided optimum access to feed with no visible feed wastage.

Experimental animals

Feed	Moisture (%)	**Ash (%)**	**Protein (%)**	**Fibre (%)**	**Fat (%)**	**Carbohydrate (%)**
Feed A	~ 10	4.60	26.18	1.20	1.12	68.10
Kelp	~ 80	28.67	9.05	8.21	0.53	61.75

Grow-out abalone, supplied by the JSP commercial abalone farm, from a single broodstock pool spawned in May 2002 were subdivided into two replicate groups of approximately 12.5kg (i.e. ± 250 individuals) per basket per diet treatment. Initial body weight and shell length were 45.65g ± 0.26 and 63.13mm ± 0.14, respectively.

Treatments

Two diet treatments were tested, each with two replicates.
Treatment 1: Fresh kelp (Ecklonia maxima) with a protein content of ca 5-15% (see Table 1 for approximate composition) was supplied ad libitum. Deteriorating kelp was removed and fresh kelp supplied daily.
Table 1. Proximal feed analysis of Feed A and kelp. Data supplied by the Animal Production Laboratory, Institute for Animal Production, Department of Agriculture: Western Cape, Elsenberg.

Treatment 2: Commercial Feed A, with a protein content of ca 26% (see Table 1 for approximate composition) containing kelp as a feeding stimulant, formalin-free fishmeal, binders, vitamins, minerals and soya, was supplied at 70g (0.56 % of the initial mean body weight) per basket per day.

Sample and data collection

Representative animals were randomly selected for measurement from each basket at monthly intervals during the six-month experiment (n = 25 per replicate at 0-3 months; n = 35 per replicate at 4-6 months, to compensate for later differential growth). Before measuring, the animals were blotted dry to remove excess water. Body weight was recorded to the nearest 0.01g using an electronic balance, and shell length along the longest axis of the shell was measured to the nearest 0.1mm with vernier callipers.

Daily increment in shell length (DISL in $\mu m.day^{-1}$) was calculated using the formula of Mai et al. (2001) and Zhu et al. (2002):

$$DISL = [(SL_t - SL_i)/ t] \times 1000$$

Where SL_t = final mean shell length (mm), SL_i = initial mean shell length (mm), and t = feeding period in days.

Specific growth rate (SGR in % body weight.day^{-1}) was calculated using the formula of Britz (1996):

$$SGR = [(\ln(Wf) - \ln(Wi)) / t] \times 100$$

Where ln(Wf) = natural log of the final mean weight of abalone, ln(Wi) = natural log of the initial mean weight of abalone, and t = feeding trial period in days.

Feed conversion ratio (FCR) was calculated using the formula of Britz (1996):

$$FCR = (ration/growth) / 100$$

Where ration = blotted wet feed intake (g) per day for kelp and dry feed intake (g) per day for commercial Feed A, and growth = blotted wet weight (g) gained per day.

The condition factor (CF), which is an index developed to account for the relationship between the weight of abalone per unit shell length, was calculated using the formula of Britz (1996)

$$CF\ (g.mm^{-1}) = [BW\ (g) / SL\ (mm)^{2.99}] \times 5575$$

Where CF = condition factor, BW = mean body weight, and SL = mean shell length, whilst 2.99 and 5575 are constants.

Statistical analyses

All data were expressed as means ± SE. Statistical analysis using one-way ANOVA and Tukey test for multiple comparison of means with 5 % significance level was applied. Differences amongst treatments were therefore considered statistically significant at $P < 0.05$. To test for correlation, body weight and shell length were compared by means of a linear regression test.

Results

Both feeds reflected a positive correlation between body weight and shell length gain (Table 2). The data show that, while the feeds generally produced similar gains in shell length ($P = 0.755$) (Fig. 1), the commercial Feed A outperformed kelp in weight gain ($P = 0.025$) (Figure 2). This is supported by data on DISL (Feed A = 46.839 $\mu m.day^{-1}$; kelp = 45.220 $\mu m.day^{-1}$; $P = 0.469$) and SGR (Feed A = 0.266 % body weight.day^{-1}; kelp = 0.257 % body weight.day^{-1}; $P = 0.014$) (Table 2). Although the feeds produced poorer FCR values (Feed A = 3.935; kelp = 42.694) than the industry norms (see e.g. Hattingh 2006), Feed A resulted in a better feed conversion efficiency than kelp, i.e. more kelp was required to produce comparable growth. The latter finding is consistent with industry norms. While all animals showed positive CF values (i.e. >1, suggesting relatively ‘fat’ individuals; see Britz 1996) at the start of the experiment, those cultured on Feed A (CF difference of 0.122, compared to a CF difference of 0.111 for kelp) were relatively ‘fatter’ (Table 2).

Table 2. Growth parameters of abalone fed Feed A and kelp. Specific growth rate (SGR, % body weight.day^{-1}), daily increment in shell length (DISL, µm.day^{-1}), feed conversion ratio (FCR), regression factor (r, r^2) and condition factor (CF) are provided for both feeds. Comparative values with the same superscript are not statistically different.

Feed	Final weight (g)	Final length (mm)	SGR	**DISL**	**FCR**	**r**	**r^2**	**Initial CF**	Final CF
Feed A	**75.204±0.725^a**	**71.516±0.215^a**	**0.266^a**	46.839^a	3.935^a	0.985	0.971	1.071	**1.193**
Kelp	**72.673±0.716^b**	**71.218±0.244^a**	**0.257^b**	45.220^a	42.694^b	0.992	0.984	1.062	**1.173**

Figure 1. Increase in shell length using the formulated Feed A and kelp.

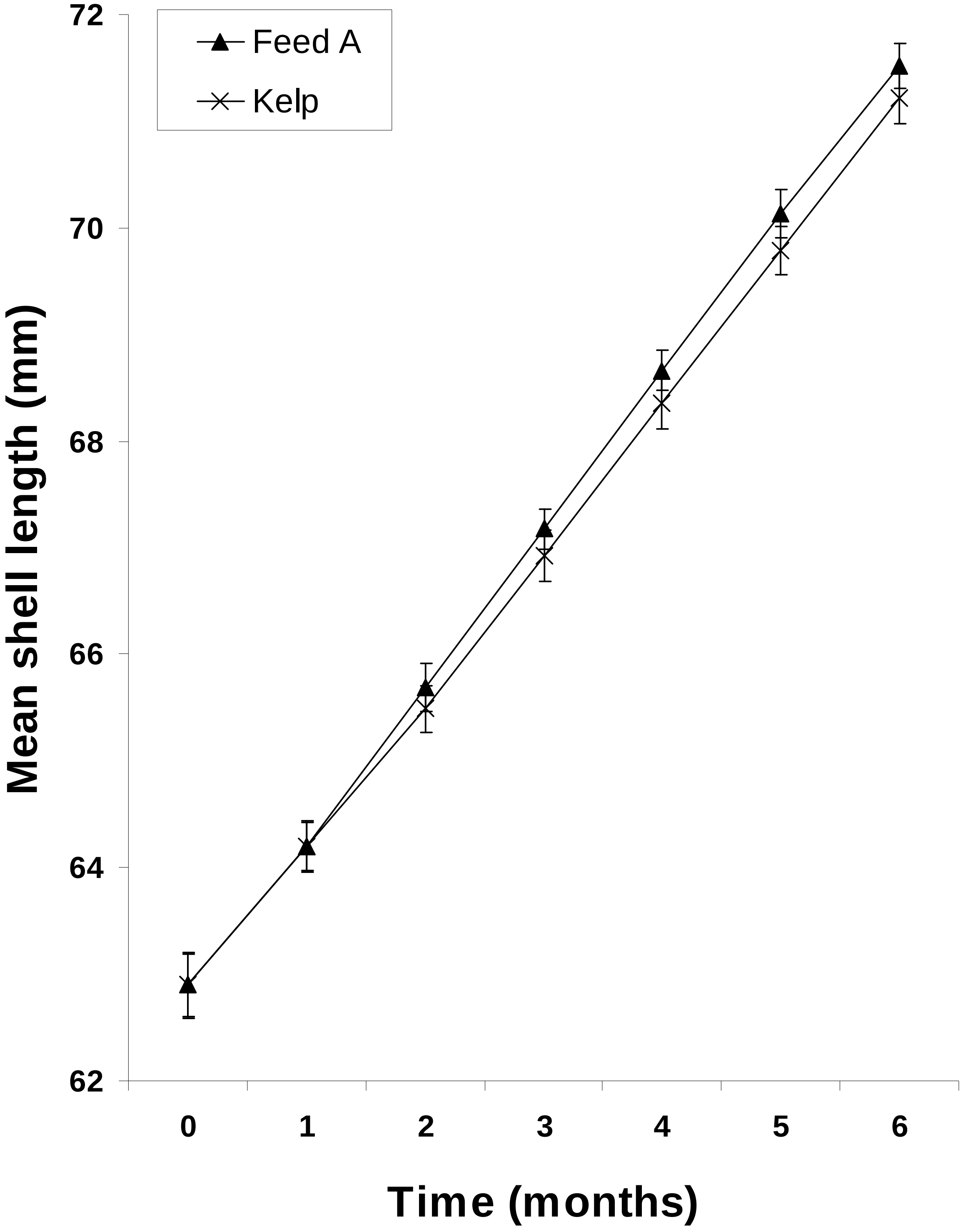
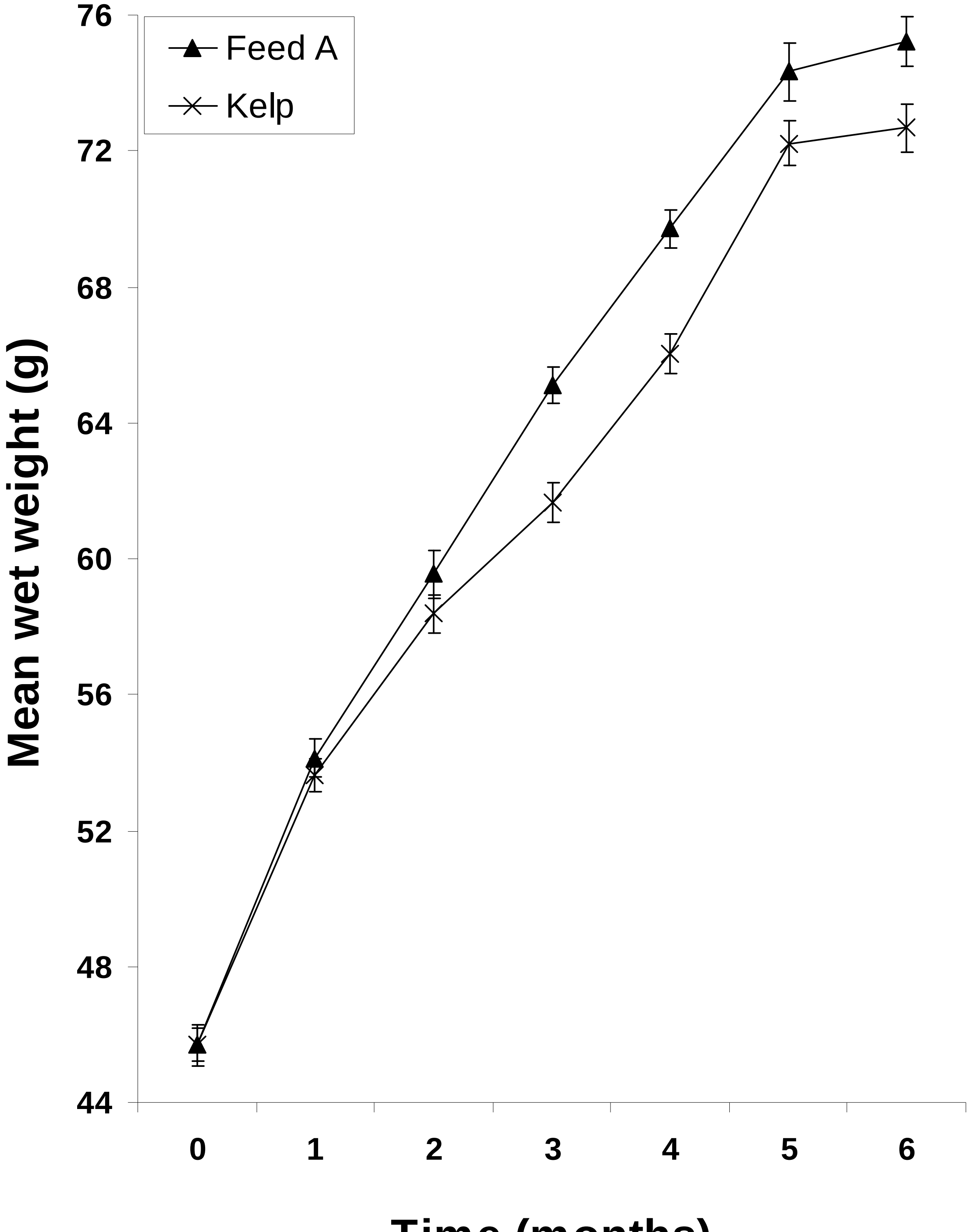


Figure 2. Increase in body weight using the formulated Feed A and kelp.



Discussion

The results of this study are consistent with those of unpublished research. Hatting (2006) showed that kelp could be included in artificial diets, and that reducing the protein level in diets of abalone larger than 50mm could be done without compromising growth. In addition, low-protein formulated feeds produced growth in large (>50mm) abalone that was comparable to that of abalone fed high-protein feeds. Our data show similar trends, in that the growth of abalone fed kelp and Feed A were comparable. What was striking in the present study was that substantially less Feed A relative to kelp was required to produce comparable growth. Our data show also that, at lower temperatures, abalone fed low-protein formulated feeds and cultured in a flow-through system, perform better than those fed kelp. This supports the use of lower-protein formulated feeds.

Protein is the most expensive component in artificial feeds (Fleming et al. 1996). Although the production of nutritionally balanced diets has been identified as crucial to the success of the South African abalone aquaculture industry, many farmers also require more from a feed than just nutritional quality. Cost-effectiveness is proving to be equally important. It must, however, be emphasised that, to determine the true cost of a feed accurately, many factors need to be considered, such as transport, labour and time, etc. In addition, it has been reported that a number of South African abalone farms are achieving substantially better growth with formulated feeds than those achieved at the Jacobsbaai Sea Products farm (Britz pers. comm.).

In conclusion, lower protein formulations could be seen as an alternative feed for future abalone aquaculture, since kelp is not only low in protein content but has also been reported to be becoming hard to obtain because it is approaching its limits of sustainable harvesting, particularly in those kelp concession areas with high concentrations of abalone farms. Commercial Feed A thus has all the benefits of both kelp (i.e. feeding stimulant) and a high-protein formulated feed (i.e. for producing meat weight gain) but none of their apparent disadvantages (i.e. potentially limited availability and low protein content of kelp; potentially higher incidence of sabellid worm infestation under poor tank hygiene and with high-protein feeds). Low-protein formulated feeds may thus prove to be of considerable benefit to the abalone aquaculture industry, particularly to those farms located at substantial distances from natural kelp stocks.

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