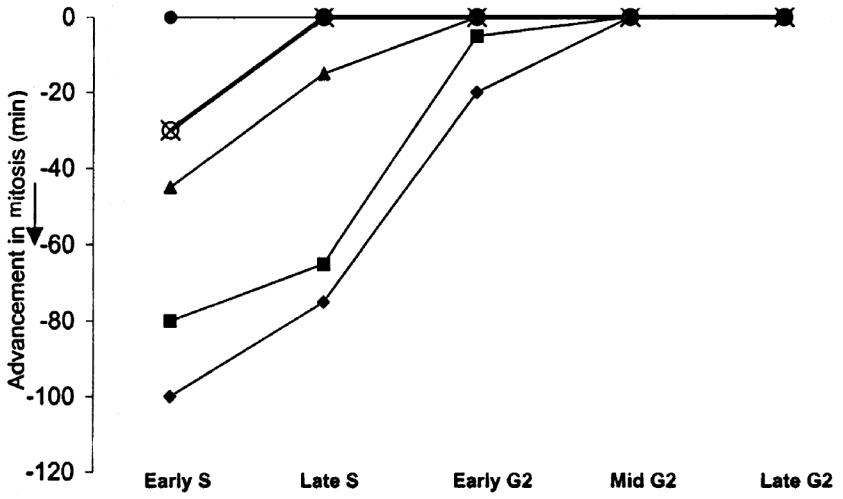

Figure 2. Gradual loss of activity of Brahmi extract on storage. –◆–, 1st day; –■–, 7th day; –▲–, 15th day; –O–, 23rd day; , –✳–30th day; –●–, 35th day. Control metaphase is denoted as the '0' point.

observed effects, but also to study the mechanism of their action on cell cycle stage-specific processes. This should also give us a better insight into the role, if any, played by synergism in the overall action of the component(s) of the extract on the cell.

1. Kinghorn, A. D., Cui, B., Ito, A., Chung, H. S., Seo, E. K., Long, L. and Chang, L. C., *Biologically Active Natural Products: Pharmaceuticals* (eds Cutler, S. J. and Cutler, H. G.), CRC Press, New York, 2000, pp. 17–24.
2. Basu, N. K. and Walia, J. S., *Indian J. Pharm.*, 1944, **4**, 84–91.
3. Chopra, R. N., Nayar, S. L. and Chopra, I. C., *Glossary of Indian Medicinal Plants*, CSIR, New Delhi, 1956, p. 32.
4. Sivarajan, V. V. and Balachandran, I., *Ayurvedic Drugs and their Plant Sources*, Oxford and IBH, New Delhi, 1994, pp. 97–99.
5. Aithal, H. N. and Sirsi, M., *Indian J. Pharm.*, 1961, **23**, 2–5.
6. Chatterjee, N., Rastogi, R. P. and Dhar, M. L., *Indian J. Chem.*, 1963, **1**, 212–215.
7. Chatterjee, N., Rastogi, R. P. and Dhar, M. L., *Indian J. Chem.*, 1965, **3**, 24–29.
8. Basu, N., Rastogi, R. P. and Dhar, M. L., *Indian J. Chem.*, 1967, **5**, 84–86.
9. Bhakuni, D. S., Dhar, M. L., Dhar, M. M., Dhawan, B. N. and Mehrotra, B. N., *Indian J. Exp. Biol.*, 1969, **7**, 250–262.
10. Elangovan, V., Govindasamy, S., Ramamurthy, N. and Balasubramanian, K., *Fitotherapia*, 1995, **66**, 211–215.
11. Singh, H. K. and Dhawan, B. N., *J. Ethnopharmacol.*, 1982, **5**, 205–214.
12. Singh, H. K., Rastogi, R. P., Srimal, R. C. and Dhawan, B. N., *Phytother. Res.*, 1988, **2**, 70–75.
13. Singh, H. K. and Dhawan, B, N., *Indian J. Pharm.*, 1997, **29**, 359–365.
14. Tripathi, Y. B., Chaurasia, S., Tripathi, E., Upadhyay, A. and Dubey, G. P., *Indian J. Exp. Biol.*, 1996, **34**, 523–526.
15. Daniel, J. W. and Baldwin, H. H., *Methods in Cell Physiology* (ed. Prescott, D. M.), Academic Press, New York, 1964, vol. 1, pp. 9–41.
16. Guttes, E. and Guttes, S., *Methods in Cell Physiology* (ed. Prescott, D. M.), Academic Press, New York, 1964, vol. 1, pp. 43–54.
17. Mohberg, J., *Cell Biology of Physarum and Didymium* (eds Aldrich, H. C. and Daniel, J. W.), Academic Press, New York, 1982, pp. 273–276.
18. Kessler, D., *Exp. Cell Res.*, 1967, **45**, 676–680.
19. Hunter, T., *Cell*, 2000, **100**, 113–127.
20. Sachsenmaier, W., Donges, K. H., Ruppf, H. and Czihak, G., *Z. Naturforsch., B*, 1970, **25**, 866–871.
21. Alberts, B., Johnson, A., Lewis, J., Raff, M., Roberts, K. and Walter, P., *Molecular Biology of the Cell*, Garland Science, New York, 2002, p. 1006.

ACKNOWLEDGEMENTS. P.R.J. and P.R.M. dedicate this paper to Dr R. Vimala Nair. T.V., D.V. and P.R.J. thank Dr M. V. Joseph, Head, Department of Biotechnology, University of Calicut, for laboratory and library facilities.

Received 16 October 2002; revised accepted 4 June 2003

T. VENU
D. VISHWANADHAM
P. R. JAYASREE
P. R. MANISH KUMAR*

Department of Biotechnology,
University of Calicut,
Calicut University P.O.,
Malappuram 673 635, India
**For correspondence. e-mail:*
manishramakrishnan@rediffmail.com

Role of plant proteins in formulated fish feeds

Sustainable fish culture is a formulated feed-based industry. Fish feeds constitute the major fraction of the operational cost in both intensive and semi-intensive culture systems globally. Protein is the major item of formulated feeds. It is required in large quantity by many cultivable fishes. Protein requirement of fishes is uniformly high irrespective of their food habits and ranging from 35 to 70% dry weight of the feed. Growth in cultivable fishes is primarily influenced by quality (amino acid composition) and quantity of proteins in the formulated feeds, compared to other farmed animals. Conventional fish meal continues to be a primary protein source in formulated feeds. But its rising cost, uncertain availability and unreliable quality have led to the scientific search for alternative sources. The utility of plant protein sources (PPS) to completely or partly replace the fish-meal is being researched meticulously. However, studies reveal negative results as reduced specific growth rate (SGR)[1–3] and reduced protein efficiency ratio (PER)[1,4–6], when PPS exceed identified levels in formulated feeds. Briefly, the balanced fish feeds to enhance maximum growth in most of the cultivable

fishes are needed urgently. Meanwhile, it is interesting to ascertain the role of PPS in formulated feeds by some comprehensive analysis of available data with suitable statistics. With this viewpoint, the relationships between the dietary crude protein (DCP in %) of the PPS-based feeds and SGR (in %) as well as PER of selected fish species were estimated and their implications are discussed.

From a systematic survey of relevant literature, 87 standard papers were selected which appeared during the period 197897. They provided immediate access to adequate and reliable estimates of DCP, PER and SGR of 53 cultivable fishes tested under normal experimental conditions on formulated fish feeds, which have been prepared from a wide variety of PPS. SGR is a more instaneous estimate of fish growth and expressed as percentage body weight gain per day.

$$\text{SGR (\%)} = \log Wt - \log Wo/t \times 100,$$

where Wo and Wt are the weight (g) at the beginning and end of the experimental period respectively and t is the time or duration of feeding (in days). PER is a simple measure for comparing protein quality of different feed stuffs and requires only an accurate measure of dietary protein intake and weight gain by fish:

$$\text{PER} = \text{Net body weight gain (g)}/\text{weight of protein intake (g)}.$$

DCP is calculated by proximate analysis of the feed for total nitrogen (in %) using Kjeldhal method, which is the converted into proteins by multiplying it with a factor 6.25 as follow:

$$\text{DCP (\%)} = \text{Weight of nitrogen} \times 6.25/\text{weight of sample} \times 100.$$

The final data set for SGRÐDCP relationship includes 377 estimates for 40 species from 64 papers. The PERÐDCP analysis, included 332 values for 38 species from 60 papers. Totally, 37 papers are common to both data sets which provided estimates of both SGR and PER for 22 species. These data sets can be obtained from the authors. They were analysed for correlation and regression.

The low (0.177), positive but significant ($P < 0.05$) r value for DCPSGR relationship clearly suggests that SGR did not show any significant increase at higher levels of DCP (Table 1). The percentage variation ($r^2 = 3.14$) explained by DCP in SGR is very low. The t test for S.E. of r provides two inferences: (i) estimated r is significantly deviated from zero, and (ii) this sample r is also significant ($P < 0.05$) at the level of population. The range of this population r as calculated from P.E. of (r) is 0.1436–0.2109. The b value of this correlation is significant at the level of population ($P < 0.05$). Its positive sign confirmed the linear relationship between DCP and SGR.

Table 1. Correlation and regression matrix for selected data sets

Statistics	Estimates	
	DCP vs SGR ($n = 377$)	DCP vs PER ($n = 332$)
Correlation coefficient (r)	0.177276*	– 0.990965*
Coefficient of determination (r^2)	0.031426	0.982015
Standard error (S.E.) of r	0.050822*	0.007383*
Probable error (P.E.) of r	0.033646	0.000665
Limits of population of r	0.1436–0.2109	– 0.9902– (– 0.9916)
t for S.E. of r	3.4881	134.2225
Regression coefficient (b)	0.177207	– 0.103604
Intercept (a)	4.37243	5.38556
S.E. of b	0.008645*	0.041433*
t for S.E. of b	20.5006	2.5005

*Significant at $P < 0.05$.

In contrast, the high (-0.990), negative and highly significant r value for DCP–PER relationship directly indicates that lower the DCP of a PPS-based feed, the higher is the PER of the fish fed on it. The percentage variation explained by DCP in PER is very high ($r^2 = 98$). The calculated r is significantly deviated from zero and also significant ($P < 0.05$) at population level. The population r ranges -0.9900.991 as estimated from P.E. of r. The b value is highly significant and its negative sign also indicated the inverse relationship between DCP and PER.

A linear relationship between optimum dietary protein estimate and SGR of 13 species was reported earlier[3,7]. It has also been confirmed by scrutinizing more data ($n = 377$ for 40 species) but using a different estimate, DCP. Fish growth is governed by a wide range of exogenous and endogenous factors in addition to DCP of fish feed[8]. Hence this discussion is restricted to the impact of DCP of the PPS-based feeds on fish growth. This is because data sets under analysis are dominated by PPS-based feeds.

Similar to our results, higher DCP levels of PPS based feeds result in reduction of SGR[1,9]. In contrast, negative correlation between SGR and DCP contents of PPS-incorporated feeds was reported for many fishes[10–11]. PER has decreased almost inversely with increasing DCP in feeds[4,10,12,13]. Conversely, enhanced PER was reported on feeds with low DCP levels[13–14]. Weight gain was decreased on feeds with a higher inclusion level of DCP[15,16]. Feeds with low DCP levels were efficiently utilized by fishes for body protein synthesis[17,18].

More strictly, fishes require a mixture of essential and non-essential amino acids. Amino-acid profiles and their bioavailability are of greater importance for growth in fishes. Quantitative and qualitative variations in amino acids of the formulated/natural feeds correspond to variations in growth parameters. A positive correlation was reported between dietary and serum-essential amino acids in many species[3]. Hence recent studies have focused on amino acid supplementation in formulated feeds. It is remarkable that assimilation efficiency of fishes is positively correlated with food nitrogen[19].

To conclude, complete understanding and documentation of available data, more systematic and holistic view of PPS evaluation, researches on amino acid supplementation, evaluation of PPS-based feeds on farm conditions and studies on responses of fish to PPS-based feeds in future will decide the role of PPS in fish feeds and profitable fish culture.

1. Higgs, D. A., Mc Bridge, J. R., Markert, J. R. and Davidson, J., *Aquaculture*, 1984, **34**, 213–228.
2. Reigh, R. C. and Ellis, S. C., *Aquaculture*, 1992, **104**, 279–292.

3. Tacon, A. and Cowey, C. B., in *Fish Energetics: New Perspectives* (eds Tytler, P. and Calow, P.), Croom Helm, Sydney, 1985, pp. 155–183.
4. Chen, H. Y. and Tasi, J. C., *Aquaculture*, 1994, **119**, 265–271.
5. Sayed, A. F. M., *Aquaculture*, 1994, **127**, 169–176.
6. Wilson, R. P., *Aquaculture*, 1994, **124**, 67–80.
7. Pandian, T. J., in *Fin Fish Nutrition Research in Asia* (ed. De Silva, S. S.), Heinemann, Singapore, 1988, pp. 52–71.
8. Weatherly, A. H. and Gill, H. S., *The Biology of Fish Growth*, Academic Press, London, 1987, p. 44.
9. Hasan, M. R., Shaba, D. K., Das, P. M. and Hossain, M. A., Proc. Fifth Asian. Fish. Nutri., AFS, Manila, 1994, p. 1573.
10. Akand, A. M., Miah, M. I. and Hague, M. M., *Aquaculture*, 1994, **77**, 175–185.
11. Habib, M. A. B., Hasan, M. R. and Akand, A. M., Proc. Fifth Asian Fish, Nutri., AFS, Manila, 1994, pp. 57–63.
12. Jauncey, K., *Aquaculture*, 1982, **27**, 43–54.
13. Santiago, C. and Reyes, O. S., *Aquaculture*, 1991, **93**, 155–165.
14. Hidalgo, M. C., Sanz, A. and Gallego, G. M., *Comp. Biochem. Physiol.*, 1993, **105**, 165–169.
15. Dabrowski, K., *Aquaculture*, 1977, **12**, 63–73.
16. Singh, B. N. and Bhanot, K. K., in *First Indian Fish Forum* (ed. Mohan Joseph, M.), AFS, India, 1988, pp. 77–78.
17. Parazo, M., *Aquaculture*, 1990, **86**, 41–46.
18. Devi, C., Vijarahavan, S. and Srinivasulu, C., *J. Aquat. Biol.*, 1998, **13**, 125–127.
19. Pandian, T. J. and Marian, M. P., *Mar. Biol.*, 1985, **35**, 301–311.

ACKNOWLEDGEMENTS. We are deeply indebted to Prof. T. J. Pandian (Madurai) for his keen interest, inspiration and invaluable inputs. Sincere thanks to Dr D. R. Kamalakannan (Madurai) for support and to Dr P. Murugavel for immense helps. TRS thanks Dr K. Balakrishnan for guidance. Thanks to Board of Madura College, Principal, HOD and faculty members.

Received 7 June 2002; revised accepted 3 April 2003

N. KRISHNANKUTTY[†,#]
T. R. SUJATHA[**]

[†]*P.G. Department of Zoology, Madura College, Madurai 625 011, India*
[**]*Department of Zoology and Microbiology, Thiagarajar College, Madurai 625 009, India*
[#]*For correspondence.*

The Jurassic ostracode fauna of Bela Island, Rann of Kachchh, Gujarat

The Jurassic ostracodes of Kachchh were first described by Lyubimova and Mohan (see ref. 1), who recorded eight species (all new) from two localities, Khavda and Lodai. Later, there were several publications on these ostracodes from Kachchh Mainland and adjoining Banni Rann[2–6]. As far as the Northern Island Belt comprising Pachchham (except Khavda), Khadir, Bela and Chorar islands, and localities south of Bhuj town are concerned, no work was done on the Jurassic ostracode fauna. Hence in 1999, one of us (S.C.K.) under a DST-sponsored research project initiated the study of Jurassic ostracodes from different stratigraphic sections covering the entire Kachchh district. As a consequence recently Khosla *et al.*[7] have recorded 54 ostracode species from the type section of the Khadir Formation, i.e. Khadir Island. The present correspondence deals with ostracode fauna from the Jurassic beds of the Bela Island.

The samples from which ostracode fauna are being recorded come from five sections which are as follows (Figure 1): Section I, exposed along LodraniKuda track, north of Lodrani village (23°54′ 29″N, 70°37′25″E) (samples BI/1–35). Section II, exposed at about 1 km NW of

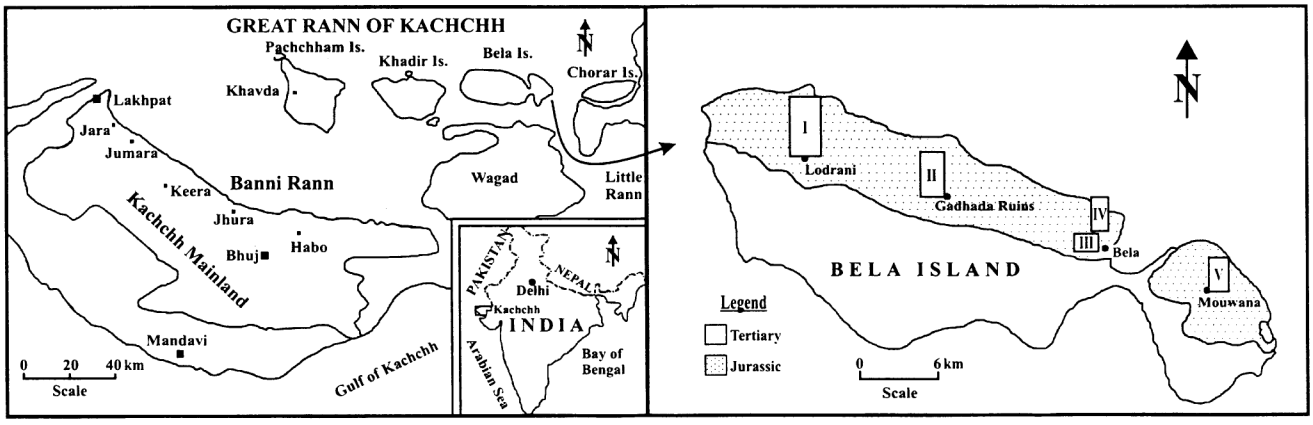

Figure 1. Sketch map of Kachchh showing location of Bela Island and Sections I–V sampled.