International Research Journal of Environmental Sciences ISSN 2319–1414
Vol. 7(2), 60-66, February (2018) *Int. Res. J. Environmental Sci.*

Review Paper

The utilization of aquatic weeds in an environmental friendly way of fish feed formulation- a review

Debashri Mondal
Department of Zoology, Charuchandra College, 22, Lake Road, Kolkata-700029, West Bengal, India
debashri_mondal@rediffmail.com

Available online at: www.isca.in, www.isca.me
Received 3rd October 2017, revised 28th January 2018, accepted 15th February 2018

Abstract

Cost of fish feed is the major concern of fish farmers in any fish culture operation. Day by day the cost of fish feed components is increasing which necessitates identification of alternative raw materials for use in feed production. It is proved experimentally that, aquatic weeds, which are generally considered as menace to pisciculture can be very much effective in providing low cost feed for most of the fishes. This kind of utilization of aquatic weeds is one of the best environmental friendly weed controlling method. This review enlightens the role of aquatic weeds as a potential fish feed and their influence on growth and survival of fish.

Keywords: Aquatic weeds, feed cost, utilization, growth, fish culture, fish feed.

Introduction

In any fish culture operation, feed cost is considered the major recurring expenditure. Apart from the livestock industry, intensive forms of aquaculture also involve optimum utilization of formulated feeds and thus increase competition for commercially available nutrient ingredients. This is exacerbated for some ingredients, thereby increasing the cost of unit production. Nowadays cost of fish-feed components are escalating; so it becomes necessary to identify alternative raw materials and their local abundance for use in feed production. These less conventional ingredients are often ideal for producing farm- based aqua feeds.

Use of these ingredients in making fish feeds based on a scientific approach can reduce their wastage, minimize cost of production and provide adequate nourishment to fish without adversely affecting the ambient environment[1].

Fish meal is a major source of dietary protein in fish and crustacean feeds because of increasing cost, considerable variation in fish meal quality and uncertainly of regular supply of reliable quality, it is essential that alternative sources of protein be identified for its partial or complete replacement. For this replacement, aquatic weeds are proved to be very much effective in providing low cost healthy fish feed.

Aquatic weeds and their classification

Aquatic weeds are defined as those unwanted and undesirable vegetation which reproduce and grow in water and if left unchecked may choke the water body posing a serious menace to pisciculture[2].

Aquatic weeds can be divided according to the softness and hardness of the stream of the plants[3]. From fisheries standpoint the most useful classification based on habit and habitat of plants are as the following: i. Floating Weeds: Floating weeds are those, which have their foliage above the surface of water with roots hanging free underneath, e.g. *Eichornia* sp., *Pistia* sp., *Lemna* sp., *Azolla* sp., *Wolffia* sp., etc. ii. Emergent Weeds: Emergent weeds are rooted in the bottombut having their foliage and flowers above the water surface, e.g. *Nymphea* sp., *Nymphoides* sp., *Nelumbo* sp., *Myriophyllum* sp., *Trapa* sp., etc. iii. Submerged Weeds: Submerged weeds are those, which may or may not be rooted, e.g. rooted ones are: *Hydrilla* sp., *Lagarosiphon* sp., *Najas* sp., *Ottelia* sp., *Potamogeton* sp. and, *Vallisneria* sp. and those devoid of roots are: *Ceratophyllum* sp., *Utricularia* sp., etc. iv. Marginal Weeds: Marginal weeds are those, which grow on the margins or on the shore line of the waterbody. They are mostly rooted in water logged soils, e.g. *Typha* sp., *Phragmites* sp., *Cyperus* sp., *Eleocharis* sp., *Panicum* sp., *Colocasia* sp., *Ipomoea* sp., etc. v. Filamentous Algae: Which form “algal mats” in and around main water body. Most prominent filamentous algae in ponds are *Spirogyra* sp. and *Pithophora* sp. vi. Planktonic algae: These are planktonic and their rapid proliferation results into algal blooms. The well known examples of this group are *Microcystis* sp. and *Anabaena* sp.

Whatever manner the aquatic weeds be classified the most important are the methods of control which can be formulated only after their identification, habit, adaptive capacity, methods of multiplication, period of dormancy of the reproductive stages and such other ecological aspects[4].

Weeds are unwanted and undesirable

One of the crucial problems confronted by Indian pisciculturists in the control of excessive growth of aquatic vegetation in waters, since its profusion there appropriates disproportionately large quantities of soluble nutrients drastically curtailing their productive role to serve economic ends. Weed chocking of a body of water severely restricts plankton production; limits the living space for fish; disturbs the equilibrium of physico-chemical qualities of water; lowers the dissolved oxygen level; promotes accumulation of deposits leading to siltation; obstruct netting operations. Moreover aquatic weeds provide harbor place not only for the molluscs and aquatic insects but also for the predatory and weed fishes which are prolific breeders and profuse feeders and over populate themselves. These factors limit the available food to the cultivable carp species resulting into less fish production.

In India, over 140 species of plants have been reported to act as aquatic weeds both within and around various kinds of water bodies. The states comprising West Bengal, Bihar, Orissa, Assam, Tripura and Manipur have maximum incidence of weed infestation ranging from 40 to 70 percent, whereas in other states, it may range between 20-50%. West Bengal fisheries in 1951 had suffered a loss of 45 million kg of fish per year due to the overgrowth of water hyacinth in 1.5 lakh ha of water area. 56 species of aquatic weeds of which 9 were floating. 11 emergent, 16 submerged and 20 marginal were identified[5].

Problem of weed infestation in Bangladesh, Burma, Sri Lanka and Indonesia are almost similar to India. In most of the African countries, the problem of weed infestation in encountered in large water bodies like reservoirs and certain slow moving rivers.

Control measures

The measures adopted for the control of aquatic weeds can be grouped into following major categories: i. Manual and mechanical methods. ii. Chemical methods, iii. Biological methods, iv. Utilization methods.

Scientists and technologists all over the world have devoted considerable time in the past to eliminate aquatic weeds by mechanical, chemical or even biological means. But all their efforts were in vein. Total eradication of aquatic weeds have been provided to be impossible, and even reasonable control has been found to be difficult. There exists no simple method for reducing the infestations. Use of herbicides and mechanical devices (adopted in the developing countries) are impractical for many developing countries due to difficulties of equipment maintenance and access to remote or swampy areas. Chemicals may adversely affect environment, and the masses of resulting organic debris may interfere with fish production.

Therefore, the scientists and technologists, gradually changed their negative attitude towards these apparently troublesome plants, and tried to turn them to productive one. Till date limited research being carried out in this field which yielded encouraging results. Aquatic weeds have been found to constitute a crop of great potential value[6].

Aquatic weeds as fish

Aquatic macrophytes are known to have potential value as human food, livestock feeder, fertilizers and food for herbivorous fishes[7].

Protein content of aquatic weeds

Aquatic weeds are good sources of protein (Table-1). The parts of the aquatic plants such as duckweeds, water hyacinth and some sobmerged weeds contain 25-29% protein which is exceptionally high. The individual amino acid constituents are present in about the same proportions as in land forages of similar crude protein content, however, the methionine and lysine amino acid levels are considered the limiting amino acids in plant proteins.

Table-1: Protein content of some aquatic weeds (Majid, 2000).

Sample	Protein % (on dry basis)
Azolla pinnata	23.03
Eichhornis crassipes	9.37-14.80
Lemna minor	20.31-23.45
Monochoria varginalis	18.75-22.50
Pistia stratiodes	12.81-13.27
Salvinia cuculata	12.8
Salvinia natans	9.37
Spirodela polyrhiza	17.25-28.39
Wolffia arrhiza	14.87-25.31
Combination	
Lemna sp., *Pistia* sp., *Spirodela* sp.	26.5
Lemna sp., *Spirodela* sp.	25.37-28.45

Mineral contents of aquatic weeds

Freshly harvested aquatic plants contain enormous quantities of minerals depending on plant type. Phosphorus, magnesium, copper, zinc and manganese were present in the same concentrations as they are in land forages, however, sodium was 10-100 times higher, Iron 4-19 times higher and potassium 3-6 times higher[4].

Categories of aqua feeds: Fish feed falls under the categories of nutrition. This concern the nature of food, food nutrients and the needs for rearing aquatic organisms. Fish feeds are mainly of two types: i. Live feed, ii. Artificial or formulated or supplementary or compound feed.

Aquatic weeds can be used both in the form of live feed as well as artificial or supplementary feed.

Aquatic weeds as live feed: Aquatic weeds are directly consumed by a number of herbivorous fishes.

Some of the important herbivorous fishes are grass carp, *Ctenopharyngodon idella*; Common carp, *Cyprinus carpio*; the golden carp, *Carassius carassius*; the gold fish, *Carassius auratus*; the tawes, *Puntius javanicus*; the nilem, *Osteochilus hasseti*; *Tilapia mossambica*, *Tilapia melanopleura*; gourami, *Osphranemus goramy, O. olfax; sepatsium, Trichogaster pectoralis*; milk fish, *Chanos chanos; Puntius dobsonii, P. pulchellus*; Silver dollar fish, *Metynnis roosevelti, Mylossoma argentums; Barbus gonionotus*; Brazilian fish, *Colossoma bidens, Mylossoma bidens*, American flag fish, *Jordanella floridae*; Channel catfish, *Ictalurus punctatus*.

An ideal herbivorous fish is the one, which is able to consume a wide variety of weeds as its food, is hardy and easy to handle, does not biologically interfere with other fishes, is economical to maintain and adds to the fishery wealth[8].

The grass carp, *Ctenopharyngodon idella* is quick growing truly phytophagus fish provided with powerful pharyngeal teeth to tear and macerate plant material. Its flesh is highly prized. The fish prefers succulent submerged weeds which are difficult to control by conventional methods. Grass carp is native to cool-water of China, but it also thrives in warm tropical waters.

In India, it was observed that grass carps stocked at 300 to 375 by numbers weighing 78.8 to 173 kg/ha, cleared a pond chocked with *Hydrilla* within a month and when stocked at 125 to 150 fish (175 to 225 kg/ha in weight), the fish consumed duckweeds at the rate of 1.8 Kg per fish per day[9]. Experiments on the efficiency of grass carp in controlling floating aquatic weeds indicated that advanced fry and fingerlings (27 to 42 mm) of the fish accepted *Wolffia* and, as they grow in size, they could take bigger duckweeds (*Lemna* and *Spirodela*). Advanced fingerlings, juveniles and adults of grass carp relish and effectively control *Azolla* and *Salvinia* Thick infestations of the submerged weeds, *Hydrilla, Najas, Ceratophyllum* can be controlled by grass carp whereas the fish has also been observed to clear infestations of *Ottlelia, Vallisneria, Nechamandra*, etc. Other weeds such as *Potamogeton, Spirogyra* and *Pithophora* are also utilized but the fish does not appear to feed actively on *Eichhornia, Pistia, Nymphoides* and *Nymphaea*[10].

In China, the fish has been reported to consume 40-70% of its own weight of grass per day and weeds can be totally eradicated with 100 fish per ha[5]. Its effectiveness has been evaluated at Alabama; grass carp measuring 25 cm to 40 cm in total length, when stocked at 40-90 per ha controlled a wide variety of weeds including *Chara, Potamogeton diversifolius, Eleocharis acicularis* and *Rhizoclonium* sp.[11]. Through the medication of grass carp in the weed control programme, satisfactory results have been reported from Japan and Malacca Fish Farm[3].

In Russia, the fish has been stocked in large reservoirs and tanks and interesting observations have been made on utilization of weeds by grass carp. It was studied that the food selectively and daily ration of grass carp in especially designed cages and categorized *Potamogeton pectinatus* as the most preferred food but *Vallisneria spiralis* and *Myriophyllum* sp. of average liking[12].

The fish ranking next to grass carp for weed control is tawes of Indonesia which feeds on selected plants belonging to the families Characeae, Ceratophyllaceae, Polygonaceae, Najadavae, Gramineae, etc. Tawes has been used for controlling submerged weeds and filamentous algae in large lakes and reservoirs in Indonesia[13].

Common carp, *Cyprinus carpio* also helps in controlling of aquatic weeds. *Ceratophyllum* and *Myriophyllum* which infest carp ponds, grey mullet nursery ponds and Tilapia breeding ponds in Israel, have been cleared completely through the agency of common carp in densities of 8,000 per ha, with an average weight of 5,000 g and above[14]. The same author has observed that filamentous algae can be chocked by stocking the ponds with common carp of 500 to 600 g weight at a density of 250 to 300 per ha. In U.S.A. It was reported that common carp stocked at 400 per ha or more could prevent the growth of submerged weeds by raking the bottom mud and thereby shading the submerged weeds[15]. Growth of filamentous algae and *Pithophora* and certain other plants with common carp at 124 per ha in bass-blue gill ponds and observed the common carp did not interfere with other species.

Tilapia has also demonstrated its suitability for weed control in ponds. In India, ponds heavily stocked with *Tilapia mossambica* have been found generally free from soft submerged vegetation and filamentous algae[5]. Other species of *Tilapia*, e.g. *T. melanopleura* and *T. zilli* are known to be even more effective than *T. mossambica*. *Tilapia melanopleura*, when stocked at 2,470 to 4,940 per ha in large impoundments, controlled a variety of weeds[11]. This species of *Tilapia* has been found useful in controlling *Chara, Najas* and other submerged soft vegetation[16].

Gourami is also known to check submerged vegetation in irrigation wells, fish ponds and reservoirs. The unsightly and clogging weeds *Hydrilla* spp. Are believed to have been controlled in ponds in Ceylon into which the gourami fish (*Osphronemus olfax*) of Java was introduced. These fishes are known to be greedy feeders of water weeds[17].

Aquatic weeds as formulated feed

Aquatic macrophytes: Water hyacinth (*Eichhornia crassipes*) is considered the least desired species among the aquatic macrophytes to be utilized by herbivorous fishes directly but attempts have recently been made to use vegetative parts of water hyacinth as fish feed in semi- digested form. Although the fish were observed to consume some of the composted material they generally obtained much nutrition from natural food in the pond generated as a product of biochemical breakdown. It was reported that enhancement of growth and feed utilization of *Oreochromis niloticus* fed with diets containing 25-75% composted water hyacinth with no significant change in physiological functions compared to the controlled diet of higher protein and energy levels[18]. Comparable growth of Nile tilapia was also observed in different diets containing 37.5% dried and composted water hyacinth (50% dietary protein) against a control diet compounded from fish-meal, groundnut cake and rice bran. The specific growth rates obtained lay between 76-94% of the control growth in static water and recirculatory aquaculture system[19]. In another experiment, Nile tilapia recorded higher growth rate (110% of control) at 20% inclusion of water hyacinth meal in the diet than control animals fed on a chicken diet.

A preliminary work on singi, *Heteropneustes fossilis*, with dried water hyacinth leaf meal at 50% inclusion level in the diet resulted in 150% more weight gain than control diet with 87% minced meat in a 20 day trial. Similarly, diets prepared with water hyacinth meal from leaves and petioles at 25% inclusion level resulted in higher growth rate and better FCR than control in fingerlings of magur, *Clarius batrachus*[20].

A 63 day trial with three species of Indian major carps (rohu, catla and mrigel) fed on diet containing 25-35% water hyacinth also showed encouraging results, both in the laboratory and under field conditions[21].

Encouraging results were recorded while working with *Brycon* sp. in cages suspended in ponds with recirculatory water systems[22]. Substitution of 9.5% and 18.9% dried water hyacinth meal in the diet resulted in SGR of 25% and 12.5% more than fish meal based controlled diet. The possible use of water hyacinth as a feed source for cage culture in Lake Rawa pening showed that substitution upto 10% in dry or composted form in the diet did not significantly decrease growth rate of Java carp, *Puntius javanicus*, common carp, *Cyprinus carpio* and Tilapia, *Oreochromis mossambicus*.

Sulvinia cuculata, commonly known as water lettuce, grows vigorously in some areas of tropical and subtropical zones during the rainy season. These free-floating weeds are seldom consumed by fish as food in fresh condition. The nutritive value of composted *S. cuculata* fed to rohu fingerlings by incorporating it into the conventional diets at 20-80% level was studied[23]. Interestingly, the diets devoid of *Salvinia* resulted in lower growth rate than diets comprising 20% composted Salvinia, though the former contained higher protein and energy levels. However, poor growth was recorded in rohu fry fed with diets containing low content (10%) of *Salvinia* powder.

The growth in *Ctenopharyngodon idella* and *Cyprinus carpio* fingerlings reared on diets made from leaf powder of *Pistia stratiodes* was studied[24]. Further the total fish production obtained in experimental diets was about 23% higher than the conventional feed.

Use of leaf meal of two aquatic weeds *Ottelia alismoides* and *Nymphoides nudicum*, as a protein source for Indian major carp fry at 30-50% inclusion level showed encouraging results compared to the conventional rice bran-ground nut oil cake mixture. The specific growth rates obtained in diets with 30% and 50% inclusion levels of *Ottelia* meal were comparable to that of control in rohu, catla and mrigal. Inclusion of *Nymphoides* meal in the diet also resulted in growth increment similar to that of *Otellia* in a 33 day rearing period.

Studies on utilization of *Ceratophylum demersum* as feed supplement revealed that its inclusion in feed formulations up to 20% along with other conventional ingredients not only increased survival rate, but significantly reduced FCR in Nile tilapia[25].

Duckweeds: Duckweeds, when cultivated in nutrient rich waters are highly productive with high protein content. Experiments revealing their inclusion in formulated fish-feeds include *Lemna, Spirodela, Azolla*, etc. Leptosorangiate fern, Azolla, has been successfully used as an organic nitrogenous fertilizer in agriculture. Besides this, *Azolla* is consumed by some macrophogous fish and also enhances nitrogen fixation in semi-intensive piscicultural systems[26]. Its use in aquaculture in recent years as a biofertilizer too could replace the use of inorganic nitrogenous fertilizers in total[27]. The use of Azolla as a non conventional feed supplement has been experimented within many species. Encouraging results were not obtained when feeding fresh *Azolla* to Nile tilapia[28]; however, they noted its effective utilization by microphyte feeding species such as *Tilapia zilli* and *T. rendalli*. Fresh *Azolla pinnata* as supplemental feed was found effective in enhancing growth of Nile tilapia fingerlings in cages in Languna lake. A comparative appetency study showed fresh *Azolla pinnata* was less preferred to *Azolla filiculoides* by fingerlings of Nile tilapia[29].

Incorporation of *A. pinnata* meal in the diet of Nile tilapia at five different levels from 8.5 to 45.5% to replace fish meal yielded positive growth response to increasing levels of dietary *Azolla* meal after 7 weeks of rearing , in spite of all feeds containing 35% crude protein and 250 kcal digestible energy/100g. This could be due to the presence of some w-6 fatty acids in Azolla, which constitute an essential dietary requirement for Nile tilapia. Similarly inclusion of *Azoll*a powder even at higher levels, from 30-6 0% in iso-nitrogenous and isocaloric diets fed to *Labeo rohita* fry showed identical results in improvement of growth performance and feed utilization efficiencies with increase in *Azolla* content in the diet[30]. Use of *Azolla* was always found to be advantageous for inclusion because of its concentrated nutrient content. Mixed residues containing cowdung and *Azolla* act as biogas generator. The digested slurry maximizes the growth of both phytoplankton and zooplankton. Conventional fish feed (20%) along with the digested slurry was observed to be most suitable as fish feed[31].

Another species of duckweed, *Spirodela* was also found to be potential; plant material for inclusion in fish diets. Feeding Nile tilapia at 5% level resulted in optimum growth with an FCR of 4.0[18]. It was studied that the growth performance of *Cyprinus carpio* fed on a diet containing 40% *Lemna minor* in an experimental trial conducted in cement cisterns and found the total weight gain in the test diet was 83% of the control group fed on groundnut cake and rice bran (1:1.5)[32]. Apparent feed conservation ratios ranging from 1.6 to 3.3 in tilapia were achieved with 3-5% feeding rate of *Lemna* on a dry-weight basis[33]. It was observed that aquatic weed, *Lemna minor* can be utilized by *Channa striatus* fingerlings in pelleted from when incorporated into a conventional diet[34]. No difference in weight was observed when commercial fish meal was substituted by 20% duckweed meal in common carp (*Cyprinous carpio*)[35]. It was also studied that 15% *Lemna* feed would be optimum for the maximum growth of *Cyprinus carpio*[36].

Algae: Generally the algal meal as a dietary protein source is known to be less effective for cumulative growth of fish. However, algal supplementation of fish feeds has certain physiological merits since algae are rich in vitamin precursor, growth promoters and essential fatty acids. In spite of their importance in enhancing growth of certain fish such as silver carp, research on the use of algae as a protein source for fish-feed formulation is scant[37]. It was demonstrated that dried Spirulina supplemented with mehionine can successfully replace fish-meal as a protein source for Nile tilapia[38]. It appears however, that the response of fish to algae is species specific. It was also reported that the superiority of an experimental diet in which Spirulina powder was incorporated to the extent of 10% of supplementary feed, when fed to fry of Indian major carps (rohu, catla and mrigal), and exotic carps (grass carp and common carp)[39]. *Spirulina* proved to be an excellent substitute for fish-meal when fed to silver seabreamat a substitution level of 50% of total dietary protein[40]. Among other algae, kelp (*Laminaria digitada*) meal fed to yellow tail (*Seriola quinqueradiata*) accelerated the accumulation of lipid reserves and activated membrane mobilization. On feeding Chlorella extract, ayu (*Pecoglossus altivalis*) not only developed resistance against *Vibrio anguillarum* infection, UDN-like ulcers and some stress factors, but also improved the lipid metabolism. In black seabream, *Acanthophagus schlegeli* supplementation of commercial diet with Ulva meal raise the protein efficiency ratio, stress resistance and lipid level[41]. However, when feeding the algal-fed cladocerans to fish and shrimp, the body weight of them increased 7% and 11% accordingly[42].

Conclusion

Aquatic weeds are still regarded by the general mass of people as a 'menace' and nuisance' because they are not aware of the great potential and economic value of these profusely growing, un-controllable plants. These highly productive plants are generally more productive than conventional terrestrial crops. Moreover, when grown on wastes, they do not compete with conventional crops for fertilizer, water or land. Their natural profuse growth in the humid tropical and subtropical areas of the world, requiring no intensive cultivation, makes them a promising source of multipurpose raw material. As a matter of fact these plants have been proved not only the good sources of fish feed but also the good sources of livestock feed, human food, soil additives and fuel. It may also be employed as an effective agent for waste water treatment. The prospect for conversion of undesirable, troublesome aquatic weeds to much needed food, feed, organic or biofertilizer, energy, fibre and paper seems to be pretty bright. So, from the above discussion it appears that if utilized properly, the aquatic weeds are not at al a 'menace' but a 'boon' to human kind.

References

1. Mukhopadhyay P.K. and Jena J.K. (1995). Use of nonconventional dietary ingredients in fish feed formulations. *Ichthyology, Recent Research Advances*, D. N. Saksena edn. Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 225.
2. Jhingran V.G. (1991). Fish and Fisheries of India. Hindusthan Publishing Corporation press, New Delhi, 415, 417-419.
3. Hickling C.F. (1962). Fish culture, London. Faber and Faber, 295.
4. Rath R.K. (2000). Freshwater Aquaculture. Scientific Publishers, New Delhi, 98-102.
5. Philipose M.T. (1966). Present trends in the control of weeds in fish culture waters of Asia and Far East. *FAO Fish Rep.*, 5 (44), 26-52.
6. Majid F.Z. (2000). Aquatic weeds utility and development. *Agrobios,* India, 8-9.
7. Edwards P. (1980). Food potential of aquatic microphytes ICLARM studies and reviews. *ICLARM*, Manila, 5, 51.
8. Avault J.W. Jr., Smitherman R.O. and Shell E.W. (1968). Evaluation of eight species of fish for aquatic weed control. *FAO fish Rep.*, 5, 109-122.
9. Alikunhi K.H. and Sukumaran K.K. (1964). Preliminary observations on Chinese carps in India. Proceedings of the Indian Academy of Sciences, sec. B, 60(3), 171-188.

10. Singh S.B., Pillai K.K. and Chakrabarti P.C. (1968). Observations of efficacy of grass carp, Ctenopharyngodon idella (Val.) In controlling and utilizing aquatic weeds in ponds in India. *Proc. Indo Pacif-Fish Coun.*, 12(2), 220-235.

11. Avault J.W., Smitherman, Jnr, R.W. and Shell E.W. (1968). Evaluation of eight species of fish for aquatic weed control. *FAO Rep.*, 44 (3), 109–122.

12. Verigin B.V., Nguen V. and Nguen D. (1963). Materials on food preference and 24 hr food intake in grass carp. In: Materialy vsesoyuz. Soveshchaniya po rybokhozyajstvennomu osvoenyu rstitel'noadnykh ryb - belogo amura (Ctenopharyngodon idella) i tolstolobika (Hypophthalmichthys molitrix) v vodoemakh SSSR. Ashkhabad, 1961. Izdat. Akad. Nauk Turkmenskoj SSR., 192-194.

13. Ling S.W. (1967). Feeds and feeding of warm water fishes in ponds in Asia and the far east. *FAO Fish Rep.,* 44(3), 291-309.

14. Pruginin J. (1968). Weed Control in Fish Pond in the Near East. *FAO Fish Rep.*, 5(44), 18-25.

15. Lawrence J.M. (1968). Aquatic Weed Control in Fish Pond. *FAO Fish Rep.,* 5(44), 76-91.

16. Blackburn R.D. (1968). Weed controlling fish ponds in the United States. *FAO fish Rep*., 5(44), 1-17.

17. King J.L. (1974). Weeds of the World Biology and Control. Wiley and Eastern Pvt. Ltd., New Delhi, 417.

18. Edwards P., Pacharaprakiti C., Kaewpaitoon K., Rajput V.S., Ruamthaveesub P., Suthirawut S., Yomjinda M. and Chao C.H. (1984). Reuse of cesspool slurry and cellulose agricultural residues for fish culture. AIT Research Report No. 166, Asian Inst. Tech., Bangkok, Thailand.

19. Pongsri C. (1986). Utilization of water hyacinth in Nile tilapia pelleted feed. (Unpublished M. Sc. Thesis) Asian Institute of Technology, Bangkok, Thailand.

20. Rath S.S. and Dutta H. (1991). Use of water hyacinth, Eichhornia crassipes as an ingredient in the feed of Clarias batrachus. *Proc. Nat. Symp. Freshwat. Aquacult*., Bhubaneswar, India, 98-99.

21. Patnaik S., Swami D.N., Rout M. and Das K.M. (1989). Water hyacinth leaf meal as a protein source in pelleted feed for Indian major carps. *Proc. Nat. Sem. Freshwat. Aquacult.*, Bhubaneswar, India, 136-138.

22. Saint-paul U., Wender U. and Teixeira A.S. (1981). Use of water hyacinth in feeding trials with Matrincha (Brycon sp.). *J. Aquat. Plant Manage.,* 19, 18-22.

23. Ray A.K. and Das I. (1992). Utilization of diets containing composted aquatic weed (Salvinia cuculata) by the Indian major carp, rohu, (Labeo rohita Ham.) fingerlings. *Biores. Technol*., 40, 67-72.

24. Murthy H.S. and Devaraj K.V. (1991). Utility of pistia (Pistia strateotes) in the diet of carps. *J. Aquacult. Trop.*, 6, 9-14.

25. Klinavee S., Tansakul R. and Promkunthong W. (1990). Growth of Nile tilapia (Oreochromis niloticus) fed with plant mixtures. In: 2nd Asian Fisheries Forum (R. Hirorano and I., Hanyu, eds.), *Asian Fish. Soc*., Manila, Philippines, 283-286.

26. Vincke P. and Micha J.C. (1985). Fish culture in rice fields. *In: Proc. 16th Sess. Int. Rice Comm.*, Los Banos, Laguna, Philippines, FAO, Rome, 297-314.

27. Ayyappan S., Dash B., Pani K.C. and Tripathi S.D. (1993). Azolla-a new aquaculture input. National meet on Aqua-farming system practices and potentials. Abstract No. OFS-2, 10-11 February, CIFA, Bhubaneswar, India.

28. Pullin R.S.V. and Almazan G. (1983). Azolla as a fish food. ICLARM Newsletter, 6 (1), 6-7.

29. Antoine T., Carraro S., Micha J.C. and Van Hove C. (1986). Comparative appetency for Azolla of Cichlasoma and Oreochromis (Tilapia). *Aquacult.*, 53, 95-99.

30. Mohanty S.N. and Dash S.P. (1995). Evaluation of Azolla caroliniana for inclusion in carp diet. *J. Aquacult. Trop*., 10, 343-353.

31. Dash D., Sikdar K. and Chatterjee A.K. (1994). Potential of Azolla pinnata as bio gas generator and a fish-feed. *Indian J. Environ. Health*, 36(3), 186-191.

32. Devaraj K.V., Rao D.K. and Keshavappa G.Y. (1981). Utilization of duckweed and waste cabbage leaves in the formulation of fish feed. *J. Agricult. and Sc.*, 15, 132-135.

33. Hasan M.S. and Edwards P. (1992). Evaluation of duckweed (L. Perpusilla and Spirodela polyrriza) as feed for Nile tilapia (Oreochromis niloticus). *Aquacult.*, 104, 315-326.

34. Raj A.J.A., Muruganandam M., Marimuthu K. and Haniffa M.A. (2001). Influence of aquatic weed (Lemna minor) on growth and survival of the fingerlings Channa striatus. *J. Inland Fish. Soc. India*, 33(1), 62.

35. Yilmaz E., Şahin A., Duru M. and Akyurt I. (2005). The effect of vary ing dietary energy on growth and feeding behaviour of common carp, Cyprinus carpio, under experimental conditions. *Appl. Ani. Behav. Sci.*, 92(1-2), 85-92.

36. Mohapatra S.B. and Patra A.K. (2013). Effect of Partial Replacement of Fishmeal with Duck Weed (Lemna minor) Feed on the Growth Performance of *Cyprinus carpio* Fry. *IOSR J. of Agricult. Vet. Sci.*, 4(2), 34-37.

37. Nakagawa H., Kasahara S. and Sugiyama T. (1987). Effect of Ulva meal supplementation on lipid metabolism of black sea bream, Acanthopagrus schlegeli (Bleeker). *Aquaculture*, 62(2), 109-121.

38. Chow C.Y. and Woo N.Y.S. (1990). Bioenergetic studies on an omnivorous fish, Oreochromis mossambicus: evaluation of utilization of Spirulina algae in feed. In: 2^{nd} Asian Fisheries Forum (R. Hirorano and I., Hanyu, eds.), *Asian Fish. Soc.*, Manila, Philippines, 291-294.

39. Ayyappan S., Pandey B.K., Sarkar S., Saha D. and Tripathy S.D. (1991). Potential of Spirulina as feed supplement for carp fry. Proceedings of the National Symposium of Freshwater Aquaculture. CIFA, Bhubaneswar, India. Bhubaneswar, CIFA. 86-88.

40. EI-Sayed A.M. (1994). Evaluation of soyabean meal, Spirulina meal and chicken offal meal as protein sources for silver seabream (Rhobdosargus sarba) fingerlings. *Aquacult.*, 127(2-3), 169-176.

41. Nakagawa H., Kasahara S., Sugiyama T. and Wada I. (1984). Usefulness of Ulva-meal as feed supplementary in cultured black sea bream. *Aquaculture Science*, 32(1), 20-27.

42. Wong M.H. and Chiu S.T. (1993). Feasibility studies on the use of sewage sludge as supplementary feed for rearing tilapia. *Environ.Tech.*, 14(12), 115-1162.