BIOLOGICAL EVALUATION OF AQUATIC PLANTS AS POTENTIAL INGREDIENTS IN SUPPLEMENTAL FEEDS FOR CHANNEL CATFISH

by

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ABSTRACT

A series of feeding trials were conducted in raceway-type aquariums with semi-purified diets for the purpose of biologically evaluating aquatic plants as diet ingredients for channel catfish. A protein concentrate extracted from water hyacinth was compared with casein for protein efficiency ratio (PER) with channel catfish fingerlings. The possibility that growth factors may be contributed by small amounts of dehydrated aquatic plant meal in the diet was tested by adding 5 or 10% water hyacinth meal or alfalfa meal to vitamin-free and vitamin-sufficient purified diets and to commercial-type diet formulations. Weight gains and mortalities were used as criteria for evaluating the experimental diets. The lengths of the feeding trials were 4 to 8 weeks depending upon the responses of the fish to the treatments.

The PER (g gain per g protein fed) for the water hyacinth protein, 0.34, was much lower than that for casein, 4.87.

Both hyacinth meal and alfalfa meal improved fish growth when added to vitamin-free diets but not when added to vitamin-sufficient diets. Water hyacinth meal provided significantly higher weight gains and lower mortalities than did commercial alfalfa meal when fed in vitamin-free diets. Water hyacinth meal did not improve the growth of fish when the plant meal was fed as 10% of commercial-type diets. The most feasible nutritional contribution of water hyacinth to channel catfish nutrition appears to be the supplementation of growth factors, when fed at low percentages, in vitamin-poor diets.

INTRODUCTION

Mechanical harvesting is one of the methods used in aquatic weed control. If these plants could be utilized for some economic purpose, such as feed for animals, this control could be changed from an expense to a profit. The use of fresh aquatic plants as feedstuff for livestock and fish has been practiced in Asia for centuries, but no attempt has been made to use them as ingredients in dried, supplemental feeds in intensive fish culture. To evaluate the plants as a possible source of nutrients for animals, extensive chemical analyses for various organic and inorganic materials have been conducted by several workers (Boyd 1968, 1969; Mixon 1970; Shirley and Easley 1970). However, no biological evaluations were conducted to test the actual productivity of these nutrients in fish or other animals.

The use of water hyacinth in large quantities in catfish rations appears impractical due to the low quantity and quality of the protein and the poor palatability; therefore, it was decided that the most practical nutritional contribution might occur as growth factors when the plant meal is fed as small percentages of the diet.

The purpose of this research was to evaluate aquatic plants, primarily water hyacinth, as an ingredient of channel catfish feeds through a series of feeding trials.

MATERIALS AND METHODS

Evaluation of Protein in Water Hyacinth. Palatability studies had shown that channel catfish did not relish feeds containing large amounts of dehydrated water hyacinth; consequently, fresh shoots of water hyacinth *(Eichhornia crassipes)* were collected from pond S-27 at the Auburn University Agricultural Experiment Station for protein extraction with a Village press. The materials were pressed for 3 to 4 hours and juice was collected. It was acidified with HCl to a pH of approximately 3.5 to precipitate the protein. The precipitate was centrifuged at 20,000 rpm for 20 minutes. The concentrate was freeze-dried, ground, then extracted three times with ethanol (8 ml/g) to yield a flavorless, lipid-free extract. It was chemically analyzed and fed in experimental diets to channel catfish fingerlings for protein evaluation.

Twenty-four, 1-cu-ft plastic tanks were set up in a laboratory in the Fisheries Building at Auburn University for the fish feeding trials. Each tank was equipped with continuously-flowing water, air, and a siphon tube to remove the bottom water. The rate of water flow was about 0.5 liter per minute.

To evaluate the protein efficiency ratio (PER) of water hyacinth protein, casein was used as a control protein. Semi-purified diets containing 12% protein, either from casein or hyacinth protein concentrate, were formulated. The composition of the diets is given in Table 1.

The diet ingredients were blended in a Hobart mixer at low speed for one hour. For purified diets water was added and mixed until a ball of dough formed. The plastic mass was frozen for several hours, grated with a household food grater and dried in a forced-air oven at 50 C for 24 hours. For commercial-type diets, the well-mixed ingredients were pelleted (5 mm long and 2 mm in diameter) with a pellet machine.

Eight tanks were each stocked with 23 channel catfish fingerlings of 108 to 124 grams in total weight. Four tanks of fish received test diet and the other fish received casein diet. All fish were fed daily with 3% of body weight of feed for 28 days. Adjustments in feed allowance were made biweekly. Weight gains and feed consumption were calculated at the end of the experiment and PER's were determined as grams of weight gained per gram of protein fed.

Growth Factors in Water Hyacinth. The shoots of the plant were dried in a large forced-air dryer at 63 C for 48 hours and ground into a 0.1-mm fine meal with a Wiley mill. The samples were analyzed for crude protein (Maro-Kjeldahl method), ash, ether extract, and cellulose. The meals were stored in air-tight containers at -18 C until used in feeding trials.

Semi-purified diets were formulated containing 5 or 10% of the dried hyacinth meal. Each was fed with and without a complete vitamin premix. The rations were quantitatively equal in protein (30%), energy, and minerals. The composition of the diets is shown in Table 2. Twenty-four tanks of channel catfish fingerlings, averaging 13 g per fish, were randomly assigned to the six test rations so that each treatment was replicated four times. The fish were fed for 28 days and weight gains were measured.

In a subsequent feeding trial water hyacinth meal was compared with alfalfa meal as a source of growth factors in semi-purified rations. Test diets were formulated containing either 10% dried water hyacinth meal or 10% alfalfa meal, each fed with and without a vitamin premix. The composition of the rations was similar to that described previously (Table 2). Four tanks of 25 channel catfish fingerlings, averaging 4 g per fish, were assigned to each ration for 42 days. Weight gains were measured and mortalities were recorded.

Water hyacinth meal was also tested in two rations containing natural feedstuffs. Both formulations contained a vitamin premix. Their compositions are shown in Table 3. Twelve tanks each containing 18 channel catfish fingerlings, averaging 7.5 g per fish, were randomly assigned to the four rations. The fish were fed daily with 3% of body weight of feed for 56 days. Weight gains were measured and feed allowance adjusted biweekly.

Table 1. Composition of semipurified diets used in determing the protein efficiency ratio of protein concentrate from water hyacinth[1].

Ingredients	Control	Experiment
Casein	15.8	0
Protein concentrate	0	32.7
Alphacel	35.2	18.3
Dextrin	28.0	28.0
Corn oil	5.0	5.0
Cod liver oil	4.0	4.0
Vitamin mix	3.0	3.0
Mineral mix	4.0	4.0
CMC	5.0	5.0

[1]Protein level: 12 per cent.

Table 2. Composition of semipurified diets used to test for growth factors in water hyacinth meal[1].

Ingredients	Casein	Casein + Vitamins	Casein + 5% HM[2]	Casein + 10% HM	Casein + 5% HM + Vitamins	Casein + 10% HM + Vitamins
Plant meal	0	0	5.2	10.3	5.2	10.3
Casein[3]	40.2	40.2	38.9	37.5	38.9	37.5
Alphacel	23.8	19.8	21.5	19.4	17.5	15.4
Dextrin	20.0	20.0	18.6	17.2	18.6	17.2
Corn oil	7.0	7.0	6.8	6.6	6.8	6.6
Vitamin mix	0	4.0	0	0	4.0	4.0
Mineral mix	4.0	4.0	4.0	4.0	4.0	4.0
CMC	5.0	5.0	5.0	5.0	5.0	5.0

[1]Protein level: 30 per cent.
[2]Water hyacinth meal.
[3]Vitamin-free casein.

Table 3. Composition of rations containing natural feedstuffs to which water hyacinth meal was added.

Ingredients	Per cent of diets
Auburn No. 2	
Soybean meal	35.0
Peanut meal	35.0
Fish meal	15.0
Distillers dried solubles	14.0
Vitamin mix	0.2
Soybean meal-fish meal	
Soybean meal	47.3
Fish meal	17.2
Corn starch	16.0
Soy oil	4.3
Vitamin mix	0.4
Lyamin (50% lysine)	0.3
Methionine	0.4
Cellulose (Solka-Floc)	14.1

RESULTS AND DISCUSSION

Protein efficiency ratio. A comparison of the quality of water hyacinth protein and casein when fed at a level to supply 12% protein in the diet, may be seen in Table 4. The PER (grams of gain per gram of protein fed), values were 0.34 and 4.87, respectively, for water hyacinth extract and casein. The difference was statistically significant ($P<.01$). However, the PER value for water hyacinth extract is slightly higher than that of green algae, *Chlorella pyrenoidosa,* which was 0.31 for the chick (Leveille *et al.* 1962). The PER value of casein for fish (4.87) in this experiment is higher than that reported for rats, 2.5, by Leveille *et al.* (1962). This is probably explained by the difference in body composition between catfish fingerlings and rats. The deficiency of amino acids such as methionine and lysine, as reported for several aquatic plants by Boyd (1968), may account for the low PER value of water hyacinth protein. Beverly *et al.* (1962) increased PER value from 2.08 to 2.74 for the rat when algae protein was supplemented by 20% of fish meal and 20% of corn.

The amino acid balance appears to be one of the factors affecting PER value of protein, therefore, the addition of deficient amino acids to diet is necessary if water hyacinth protein is to be used as fish feed. Processing may also affect quality. Cook (1962) improved the PER and digestibility of green algae by boiling the algae for 30 minutes.

Growth factors in water hyacinth meal. The addition of 5 and 10% of water hyacinth meal to vitamin-free diets improved both weight gain and survival of channel catfish fingerlings (Table 5). Rations with a complete vitamin premix but no plant meal gave slightly better growth than those supplied with plant meal and no vitamins. Adding the plant meal to diets containing the vitamin premix did not show a growth advantage. Apparently, the plant meal contributed no growth factors which were not supplied in the vitamin premix. In vitamin-poor rations, small quantities of plant meal could promote growth in channel catfish. Neogi and Rajagopal (1949) extracted 54.2 mg of carotene, a precursor of vitamin A, from one kilogram of fresh leaves. Sircar and Ray (1961) found growth substances in the root of hyacinth which enhanced the growth of rice. Sheikh *et. al.* (1964) showed that the growth substances could accelerate the alcoholic fermentation of yeast. However, the effect of these materials and other unidentified factors contributing to the growth of fish have not been investigated in water hyacinth.

Table 6 shows that at 42 days water hyacinth meal provided higher rates of growth than did commercial alfalfa meal when added to vitamin-free diets. To the diets sufficient in vitamins, the addition of neither plant meal contributed to the nutritional value. All fish gained weight to the fourth week of feeding but thereafter weight losses occured for the fish fed the basal diet and that containing alfalfa meal without vitamins.

The mortalities of fish on the basal and the basal + alfalfa meal diets were appreciable after four weeks of feeding (Table 7). No mortality at the fourth week and only 3% after the fourth week were observed for fish fed the basal + hyacinth meal ration. This suggestes that water hyacinth meal is superior to alfalfa meal in providing a source of growth factors for catfish feeds.

The addition of 10% water hyacinth meal to the vitamin-sufficient Auburn No. 2 ration did not improve the growth of fish (Table 8). The per cent weight gains of fish fed Auburn No. 2 containing plant meal were always lower than those fed Auburn No. 2 alone. For the ration of 47% soybean meal plus 17% fish meal, water hyacinth meal gave slightly higher gains for the first four weeks, but thereafter lower weight gains occurred for the fish fed hyacinth meal. The slightly, but not statistically significant, lower weight gains of fish fed the hyacinth meal rations is possibly due to lower palatability caused by the water hyacinth meal. It is also possible that 10% of water hyacinth meal in rations depresses growth. Five per cent water hyacinth meal in commercial-type rations may be more practical. In poultry, Lepkovsky *et al.* (1950) found that a natural substance which was present in dehydrated alfalfa meal depresses the growth of chicks. Heywang (1950) suggested that a 5% of alfalfa meal in diet did not significantly depress growth or egg production in any case. German and Couch (1950) added 3 mg of copper per pound of feed and showed that no apparent effect on growth of chicks occurred when fed a ration containing 10% alfalfa meal. The possibility of a depressing agent present in water hyacinth needs to be studied before using the plant for fish feed.

SUMMARY

Channel catfish fingerlings were fed with purified and commercial-type diets for the purpose of biologically evaluating aquatic plants as ingredients in supplemental feeds for channel catfish. The protein efficiency ratios (PER), expressed in grams gain per gram of protein fed, were 0.34 and 4.87 for water hyacinth extract and casein, respectively.

To vitamin-free rations, the addition of 5 to 10% hyacinth meal in diets contributed higher weight gains and lower mortality to the channel catfish.

Water hyacinth meal was superior to commercial alfalfa meal in providing growth factors to vitamin-free diets. The addition of 10% water hyacinth meal in the vitamin-sufficient commercial-type rations did not improve the growth of fish.

The contribution of growth factors when water hyacinth meal is fed at a low percentage in vitamin-poor diets appears to be the most feasible nutritional value of this plant.

LITERATURE CITED

Beverly, A. F. Erchul and Don L. Isenberg. 1968. Protein quality of various algae biomasses produced by a water reclamation pilot plant. J. Nutr. 95: 374-380.

Boyd, C. E. 1968. Fresh-water plants: a potential source of protein. Econ. Bot. 22: 359-368.

Cook, B. B. 1962. The nutritive value of waste grown-algae. Amer. J. Pub. Health, 52: 243-251.

Germem, H. L. and J. R. Couch. 1950. The effect of feeding varying levels of dehydrated alfalfa leaf meal on the growth of chicks and poultry. Poultry Sci. 29: 841-845.

Heywang, Burt W. 1950. High levels of alfalfa meal in diets for chickens. Poultry Sci. 29: 804-811.

Lepkovsky, S. W., S. D. Peterson and R. Perry. 1950. Alfalfa inhibitor in chick rations. Poultry Sci. 29: 208-213.

Leveille, G. A., H. E. Sauberlich and J. W. Shockley. 1962. Protein value and the amino acid deficiencies of various algae for growth of rats and chicks. J. Nutr. 76: 423-428.

Mixon, W. W. 1970. Environmental influences of alligatorweed control by *Agasicles* beetles. M. S. Thesis. Auburn University. 58 p.

Neogi, S. and K. Rajagopal. 1949. A method for the production of carotene concentrate from water hyacinth *(Eichhornia crassipes).* J. Sci. Ind. Res. India 8 B(7): 119-121.

Sheikh, N. M., S. A. Ahmed and S. Hedayetullah. 1964. Pakistan J. Sci. Ind. Res. 7: 96-102.

Shirley, R. L. and J. F. Easley. 1970. Observations on the chemical content of aquatic plants in Florida throughout the year. Proceedings Aquatic Plant Research Conference Florida's Aquatic Weed Menace. 44-59.

Sircar, S. M. and Arati Ray. 1961. Growth substances separated from the root of water hyacinth by paper chromatography. Nature, Lond. 190 (4782): 1213-1214.

Table 4. Protein efficiency ratios of casein and protein concentrate from water hyacinth for channel catfish fingerlings.

Protein source	Number of fish tested	4-week gain	Protein efficiency ratio
		(g)	(g gain/g protein fed)
Casein	86	158	4.87
Water hyacinth protein	92	11	0.34

Table 5. Growth and mortality of channel catfish fingerlings receiving diets containing water hyacinth meal.

Diet	Per cent weight gain	Per cent mortality
Basal	1.48	28
Basal + Vitamins	31.71	0
Basal + 5% HM	19.62	0
Basal + 10% HM	25.42	0
Basal + 5% HM + Vitamins	32.68	0
Basal + 10% HM + Vitamins	32.32	0

Table 6. Growth of channel catfish fingerlings receiving diets containing either watery hyacinth meal (HM) or alfalfa meal (AM).

Diet	Per cent weight gain	
	28 days	42 days
Basal	12.05	-1.54
Basal + Vitamins	50.71	72.04
Basal + 10% HM	16.92	15.17
Basal + 10% AM	14.08	-4.53
Basal + 10% HM + Vitamins	44.71	72.11
Basal + 10% AM + Vitamins	54.29	79.05

Table 7. Mortality of channel catfish fingerlings receiving diets containing either water hyacinth meal (HM) or alfalfa meal (AM).

Diet	Per cent mortality	
	28 days	42 days
Basal	2	22
Basal + Vitamins	0	0
Basal + 10% HM	0	3
Basal + 10% AM	3	37
Basal + 10% HM + Vitamins	0	0
Basal + 10% AM + Vitamins	0	0

Table 8. Growth of channel catfish fingerlings receiving diets of commercial-type rations with or without 10 per cent of water hyacinth meal (HM).

Diet	Initial weight (g)	Per cent weight gain			
		2 wks	4 wks	6 wks	8 wks
Auburn No. 2	135	56.6	103.0	178.1	271.7
Auburn No. 2 + HM	138	42.0	98.0	172.5	244.0
Soybean meal-fish meal	134	45.5	105.5	189.3	302.2
Soybean meal-fish meal + HM	135	47.4	109.1	179.5	267.7