Summer yield of fish in polyculture in Transkei, South Africa, using pig manure with and without formulated feed

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A high density fish polyculture investigation was conducted during the summer season of 1984 – 1985 at the Umtata Dam Fish Research Centre, Transkei. Fish species used, included the cross-breed between the Israeli Dor 70 and the Aischgrund varieties of the European common carp *Cyprinus carpio*, bighead carp *Aristichthys nobilis*, black carp *Mylopharyngodon piceus*, grass carp *Ctenopharyngodon idella*, silver carp *Hypophthalmichthys molitrix* and tilapia, *Oreochromis mossambicus*. Fresh pig manure was used as nutrient to stimulate pond productivity. In addition, some ponds also received formulated feed. With pig manure alone, a net fish production of 1,66 t ha^{-1} was achieved over a period of 175 days. Where feed was also provided to the fish, the fish yield over the same period amounted to 8,57 t ha^{-1}. The pond water effluent was used for vegetable production.

S. Afr. J. Anim. Sci. 1986, 65 – 71

'n Hoëdigtheid-vispolikultuurproduksieproef is gedurende die somerseisoen van 1984 – 1985 by die Umtatadam Visnavorsingstasie uitgevoer. Die vissoorte wat gebruik is, het ingesluit die Europese gewone karp *Cyprinus carpio*, dikkopkarp *Aristichthys nobilis*, swartkarp *Mylopharyngodon piceus*, graskarp *Ctenopharyngodon idella*, silwerkarp *Hypophthalmichthys molitrix* en die kurper *Oreochromis mossambicus*. Vars varkmis is as voedingstof gebruik om die visdamproduktiwiteit te verhoog. Vis in sommige damme het ook voedsel ontvang. Deur slegs varkmis te gebruik, kon meer as 1,66 t ha^{-1} vis binne 'n periode van 175 dae geproduseer word. Met die byvoeging van voedsel, is die visproduksie verhoog tot 8,57 t ha^{-1}. Die bemeste water uit die visdamme is aangewend vir groenteproduksie.

S.-Afr. Tydskr. Veek. 1986, 16: 65 – 71

Keywords Aquaculture, fish production, polyculture, integrated farming, piggery wastes.

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Received 11 June 1985

Introduction

The use of animal wastes in fish production systems, has been widely practised for centuries in the Far Eastern countries (Bardach, Ryther & McLarney, 1972). Considerable research has been done in this field (Schroeder 1974, 1975a, b, 1980; Moav, Wohlfarth, Schroeder, Hulata & Barash, 1977; Wohlfarth, 1978; Sin, 1980; Hopkins & Cruz, 1982). However, because of the necessity of finding substitute nutrients for fish production systems on the one hand, and the disposal of unwanted animal wastes on the other hand, more scientific work on the use of poultry and livestock manure in pond fish production systems is required.

Investigations by Prinsloo & Schoonbee (1984a, b, c) on the production of warm water fish in polyculture during the late summer and autumn periods in Transkei, using pig, cattle or chicken manure with and without formulated fish feed, clearly showed that pond fish production can be implemented successfully in temperate regions of southern Africa. These studies also confirmed research findings elsewhere in the world, namely that organic wastes which in many instances might pose a health hazard if disposed of in some other way, can be used beneficially as a nutrient in fish-pond ecosystems (Woynarovich, 1956, 1957; Tang, 1970; Bardach, Ryther & McLarney, 1972; Rappaport, Sarig & Bejarano, 1977; Buck, Baur & Rose, 1979; Edwards 1980; Schroeder, 1980; Hepher & Pruginin, 1981; Joseph, 1981; Chesnin, 1982; Hopkins & Cruz, 1982).

Although the research findings of Prinsloo & Schoonbee (1984a, b, c) emphasized the importance of declining water temperatures as a growth-limiting factor amongst warm water pond fish, the selection of the right combination of fish species using the various niches in a fish-pond ecosystem may still result in appreciable fish growth and a satisfactory feed conversion at temperatures below 20°C. The present investigation deals with fish production in polyculture under optimal summer conditions in Transkei, where the mean water temperatures in the fish-ponds usually exceeded 20°C for at least five consecutive months of the year, i.e. during the period October 1984 (Spring) to March 1985 (Autumn).

Procedure

Fish species

The pond fish used during the present investigation included the same species used by Prinsloo & Schoonbee (1984a, b, c) namely a cross-breed of the Israeli Dor 70 and the German Aischgrund varieties of the benthic-feeding European common carp *Cyprinus carpio* L. (Cronje, 1981), the Chinese carp *Aristichthys nobilis* (Richardson) (bighead carp —

zooplankton feeder), *Mylopharyngodon piceus* (Richardson) (black carp — snail feeder), *Ctenopharyngodon idella* (Val.) (grass carp — macrophyte and filamentous algal feeder), *Hypophthalmichthys molitrix* (Val.) (silver carp — detritus and phytoplankton feeder), and the cichlid *Oreochromis mossambicus* (Peters), a detritus, phytoplankton and filamentous algal feeder.

With the exception of the black carp, which was imported from Israel and which had not yet reached maturity, all other fish were spawned and grown to fingerling size at the Umtata Dam Fish Research Centre (Prinsloo & Schoonbee, 1983; Schoonbee & Prinsloo, 1984).

Fish-ponds

A total of six ponds, each 200 m^2 big and located at the Umtata Dam Fish Research Centre were used. All the ponds were of earthern construction and supplied with a monk overflow system through which water could be diverted either into other ponds or to bypass the system for vegetable cultivation. The mean depth of the ponds when full, was 0,75 m. The water used was piped from a weir in the head waters of the Umhlahlane river some 50 km from the site, from where the water was gravity-fed to the various ponds after being screened to exclude predators, such as *Xenopus*.

The water from this river system was generally of good quality being almost neutral in pH at the point of discharge into the ponds. However, both hardness and pH of the pond water increased partly as a result of the periodic liming (150 kg ha^{-1}) of the ponds which was applied fortnightly together with ammonium sulphate (70 kg ha^{-1}) and superphosphate (60 kg ha^{-1}).

Application of manure and formulated feed

Two sets of three ponds each were used with one set receiving manure only as nutrient, whilst the fish in the other three ponds also received the formulated feed. The formulated feed consisted of an 18% CP commercial chicken layer ration (Epol) in contrast to the more expensive, better quality (45% CP) fish feed used by Prinsloo & Schoonbee (1984a, b, c). Fresh pig manure with an average moisture content of 75% was obtained from a nearby piggery belonging to the local prison in Umtata. Collections were made daily for 5 days per week and transferred to the fish ponds, where it was accumulated for the purpose of application in 1 000 l containers. Application of the manure to the ponds was made for 6 days per week before 10h00 in the morning. The different quantities of manure used were mixed with water before being scattered over the ponds. Formulated feed provided to fish in the other ponds in addition to manure, was applied in the predetermined daily quantities by means of demand feeders located in the ponds concerned.

The quantities of manure used in both pond systems, expressed in kg ha^{-1}, were based on a percentage of the calculated standing crop of fish present in the ponds (see Tables 3 and 4). The quantities of formulated feed applied, based on a percentage of the total fish biomass at a given time, is presented in Table 3. The mean daily quantities of manure used in ponds where it was applied with feed, (expressed as percentage dry mass) fluctuated between 0,7% and 2,3% of the total fish mass in the ponds compared to 2,4% and 6,7% where manure alone was applied. There was a gradual increase in the manure quantities used during the first 3 months with a reduction in dosage levels towards the end of the experiment (see Tables 3 and 4). This was found necessary as problems were occasionally experienced with low oxygen concentrations in the ponds as a result of the high daily quantities of manure used. This low dissolved oxygen concentration mainly occurred in ponds receiving manure and feed, therefore aeration was provided from the third month (December) of the investigation onwards.

Physical and chemical conditions in the individual fish-ponds (Table 1) were monitored twice per week between 07h00 and 08h00 when the oxygen concentration in the ponds was known to be at its lowest (Hepher & Pruginin 1981; Prinsloo & Schoonbee, 1984a). Analysis of the water was done according to APHA (1980) whilst water temperatures in the ponds were continuously recorded on a Thies hydrothermograph provided with a 7-day recorder.

Results

Chemistry of pond water

With the exception of the conductivity of the pond water, all other physical and chemical parameters analysed showed considerable fluctuation in values obtained in both pond systems (Table 1). Extremely low minimum values were found at times in both pond systems during the present study, in contrast to the findings of Prinsloo & Schoonbee (1984a, b, c) when oxygen levels were on average much higher. Some bias is introduced in the values indicated for this parameter, as samples were taken during the early morning hours, at the onset of photosynthetic activities of algae which may result in super saturated-conditions in ponds later in the day (Prinsloo & Schoonbee, 1984a, b, c; Hepher & Pruginin, 1981). In fact, values obtained for chlorophyll-a in ponds receiving manure plus feed, usually exceeded 130 $\mu g l^{-1}$ with maximum values as high as 227 $\mu g l^{-1}$. In the ponds receiving manure only, the values for chlorophyll-a concentrations varied from 66,6 $\mu g l^{-1}$ during the onset of the experiment to a maximum of 185,7 $\mu g l^{-1}$. These values compare well with the results obtained by Hepher (1962) for fertilized fish-ponds in Israel.

Table 1 Summary of physical and chemical conditions in fish-ponds receiving pig manure only and pig manure and formulated feed.

		Pig manure only			Pig manure plus feed		
Measurement	*N*	$\bar{x}$	*Sx*	*CV*	$\bar{x}$	*Sx*	*CV*
Dissolved oxygen, mgl^{-1}	42	2,73	1,55	56,8	3,85	1,84	47,8
pH	39	7,26	0,47	–	7,31	0,37	–
Conductivity, $\mu S\ cm^{-1}$	41	218	18,19	8,3	189	21,04	11,1
Alkalinity as $CaCO_3$, mgl^{-1}	42	27,25	10,29	37,8	21,2	8,56	40,4
Total hardness as $CaCO_3$, mgl^{-1}	39	40,89	15,74	38,5	33,2	12,46	37,5
Nitrate (NO_3), mgl^{-1}	42	1,520	2,120	139,5	1,390	0,590	42,4
Ammonia (NH_4), mgl^{-1}	42	0,288	0,128	44,4	0,221	0,098	44,3
Orthophosphate (PO_4), mgl^{-1}	42	0,102	0,069	67,6	0,112	0,077	68,8

Fish yields

Results on the numbers and mass of fish stocked, the actual and calculated standing crop in the ponds over the study period, yields obtained (kg ha^{-1}), calculated daily yield (kg $ha^{-1}d^{-1}$) as well as the final results, are summarized in Tables 2, 3 and 4 and Figures 1 and 2.

Mean values for pond water temperature remained above 20°C for five consecutive months (November 1984 – March 1985) (Tables 3 and 4). A comparison of results on the yields obtained for the different fish species in ponds where only manure was used with that of the ponds where feed was also added (Table 2), clearly showed some interesting tendencies on the differing abilities of the individual fish species to use the nutrients provided to the fish-pond ecosystem. With the

Table 2 Individual contribution of the various fish species to the total yield in the two sets of three ponds each receiving pig manure with and without formulated feed.

	Stocking density and initial biomass ha^{-1}			Final individual and total fish biomass			
Fish species	Numbers	Mean total biomass (kg)	Percentage of total biomass	Numbers	Mean total biomass (kg)	Fish yield (kg ha^{-1})	Percentage contribution to total yield
Ponds receiving pig manure only							
Common carp	7 000	302,4	45,8	6 550	691,5	389,1	23,4
Bighead carp	750	19,9	3,0	700	316,0	296,1	17,8
Black carp	500	193,6	21,1	450	142,5	2,9	0,2
Grass carp	750	35,9	5,4	650	280,7	244,8	14,7
Silver carp	2 500	82,7	12,5	1 600	630,0	547,3	32,9
Oreochromis	5 000	100,6	12,2	2 150	264,0	183,4	11,0
Total	16 500	661,1	100,0	12 100	2 324,7	1 663,6	100,0
Ponds receiving pig manure and pellets							
Common carp	7 000	324,2	42,5	6 300	5 766,9	5 442,7	63,5
Bighead carp	750	25,6	3,3	750	581,4	55,8	6,5
Black carp	500	149,0	19,5	500	365,6	216,6	2,5
Grass carp	750	35,6	4,7	750	642,1	606,5	7,1
Silver carp	2 500	128,3	16,8	1 900	1 134,9	1 006,6	11,7
Oreochromis	5 000	100,6	13,2	3 950	844,2	743,6	8,7
Total	16 500	763,3	100,0	14 150	9 335,1	8 571,8	100,0

Table 3 Results obtained on the combined mean growth and production of the European common carp, the Chinese bighead, black, grass and silver carps, and *Oreochromis* used in polyculture in ponds receiving pig manure and formulated feed during the period October 1984 – March 1985 (175 days)

			Empirical values based on final numbers and biomass for each species							
Period	Days	Date	Mean and range pond temperature for period (°C)	Stocking (s) and final (f) densities (fish ha^{-1})	Standing crop (kg ha^{-1})	Yield increment (kg ha^{-1})	Yield (kg $ha^{-1}d^{-1}$)	Manure applied (as dry mass) for each period (kg ha^{-1})	Pelleted feed applied for each period (kg ha^{-1})	FCR (Feed conversion ratio)[a]
0	1	1.10.84		16500(s)	763,32					
1	29	1/10 – 29/10	16,8 14,9 – 20,5	14500	1320,92	557,6	19,2	610,0	805,6	1,4
2	58	30/10 – 27/11	20,2 17,1 – 22,5	14500	2536,69	1215,8	41,9	1700,9	2936,8	2,4
3	87	28/11 – 26/12	22,3 18,3 – 25,9	14400	3983,50	1446,8	49,9	2542,5	5264,5	3,6
4	115	27/12 – 23/1	24,2 21,4 – 27,5	14150	5732,35	1748,9	62,5	3025,0	5182,3	2,9
5	143	24/1 – 20/2	22,4 16,3 – 27,3	14150	7736,04	2003,7	71,6	2799,4	5477,5	2,7
6	175	21/2 – 25/3	20,0 18,8 – 24,9	14150(f)	9335,18	1599,1	50,0	1960,0	6473,8	4,0

[a]Calculations based on application rates of feed used.

Table 4 Results obtained on the combined mean growth and production of the European common carp, the Chinese bighead, black, grass and silver carps, and cichlid *Oreochromis* used in polyculture in ponds receiving pig manure only during the summer period October 1984 – March 1985 (175 days)

			Empirical values based on final numbers and biomass for each species						
Period	Days	Date	Mean and range pond temperature for period (°C)	Stocking (s) and final (f) densities (fish ha^{-1})	Standing crop (kg ha^{-1})	Yield increment (kg ha^{-1})	Yield (kg $ha^{-1}d^{-1}$)	Manure applied (as dry mass) for each period (kg ha^{-1})	MCR (Manure conversion ratio)[a]
0	1	1/10		16500(s)	661,05				
1	29	1/10 – 29/10	16,8 14,9 – 20,5	12100	872,48	211,43	7,3	610,0	2,9
2	58	30/10 – 27/11	20,2 17,1 – 23,5	12100	1186,34	313,86	10,8	1700,0	5,4
3	87	28/11 – 26/12	22,3 18,3 – 25,9	12100	1414,96	228,62	7,9	2730,0	11,9
4	115	27/12 – 23/1	24,2 21,4 – 27,5	12100	1793,05	378,09	13,5	3150,0	8,3
5	143	24/1 – 20/2	22,4 16,3 – 27,3	12100	2245,84	452,79	16,2	3775,0	8,3
6	175	21/2 – 25/3	20,0 18,8 – 24,9	12100(f)	2324,55	78,71	2,5	3520,0	44,7

[a]Calculations based on manure quantities added

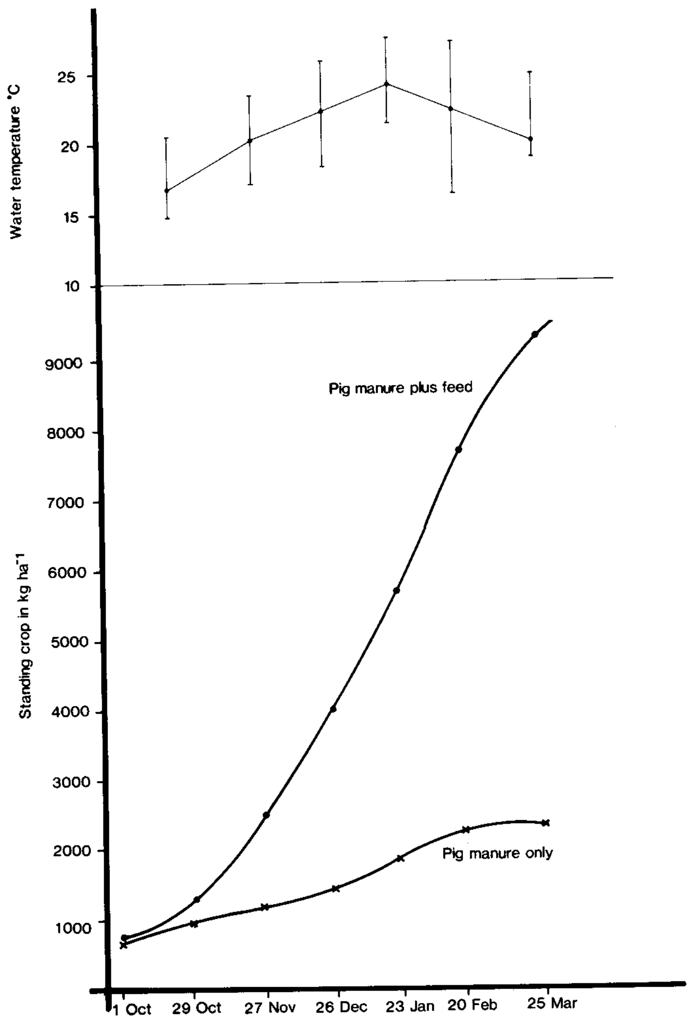

Figure 1 Standing crop in kg ha^{-1} in ponds receiving pig manure with and without formulated feed

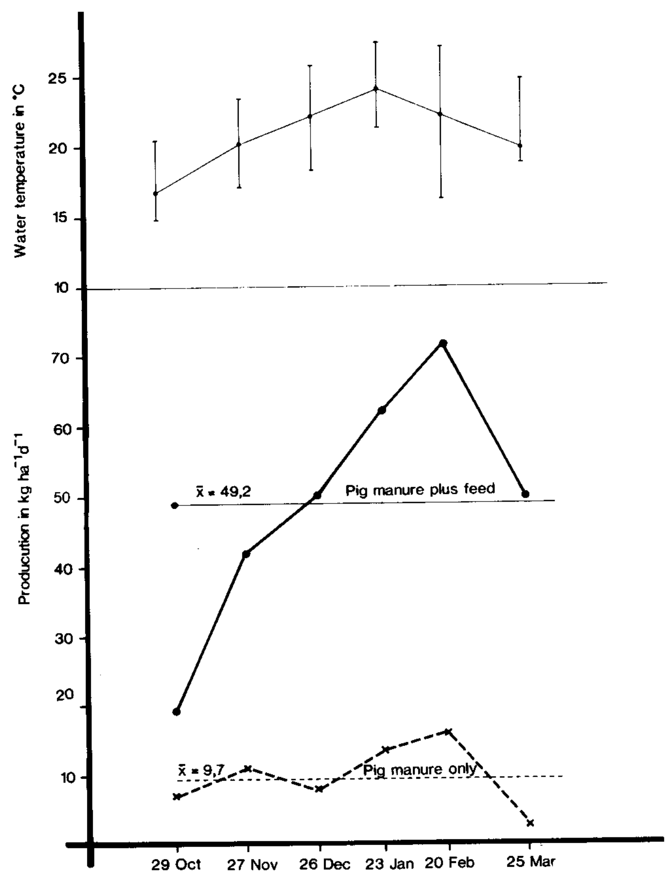

Figure 2 Production in kg $ha^{-1}d^{-1}$ in ponds receiving pig manure with and without pelleted feed for the period October 1984 to March 1985

addition of manure only, the fish species which increased their relative importance in terms of percentage contribution to biomass over the production period, included the silver carp (12,5 – 32,9%), bighead carp (3,0 – 17,8%) and the grass carp (5,4 – 14,7%). The benthic-feeding common carp showed a considerable relative decline (45,8 – 23,4%). The black carp likewise declined from 21,1% to 0,2%. The contribution by the cichlid *Oreochromis* remained virtually the same (12,2 – 11,0%).

When the results are compared with those obtained from ponds where feed was used in addition to the manuring program, an entirely different picture emerged (Table 2). The common carp clearly increased its share from an initial 42,5% to 63,5%. The bighead carp almost doubled its relative contribution (3,3 – 6,5%), whilst the grass carp was another species which increased its relative contribution towards the eventual total fish yield obtained at the end of the trial. The black carp again was not well-suited to the fish polyculture system in ponds in Transkei with its eventual relative contribution declining to 2,5% from an original 19,5%. The relative decline in the contribution by the silver carp and *Oreochromis* may perhaps be explained by high mortalities which occurred amongst these fish during the initial stage of the trial.

If the actual total yield of all the species used in ponds receiving feed plus manure is considered, the total production of 8,6 t ha^{-1} over a period of 175 days must be considered as exceptionally high for conditions in Transkei. A fish yield of 1,7 t ha^{-1} over the period of 175 days using pig manure alone is satisfactory. Also the conversion ratio of manure added, into fish so produced, remained reasonably good until the last 32 days (Table 4) when the conversion figure deteriorated rapidly. A similar tendency was experienced for this same period in the growth performance of fish in ponds receiving manure plus feed which also clearly affected the overall feed conversion ratio at a time when most of the fish species had already exceeded their minimum marketable sizes.

Vegetable production

Effluent water from manured fish-ponds were periodically drained and the ponds supplemented with fresh water to reduce the organic loads in the ponds and at the same time increase the recycling volume of the piggery wastes through the ponds. The effluent was then used to irrigate a 600 m^2 vegetable garden.

The production of vegetables from this garden, expressed in tons per hectare is listed in Table 5. On average, a crop production of 21,8 t ha^{-1} over a period of 120 days was realized. Highest production was realized from cucumbers (53,4 t ha^{-1}) followed by spinach, carrots, potatoes and cabbage, in that order.

The metered volume of effluent water used for irrigation over this period, amounted to approximately 1 000 m^3ha^{-1}. The importance of this venture was the fact that water, which otherwise would have been disposed of unused, could be used to integrate vegetable production with the pig-cum-fish production system, a practice which may be an important factor in the eventual success of the integration of fish culture with agriculture in southern Africa.

Table 5 Vegetable crop production during the period December 1984 – March 1985 at the Umtata Dam Fish Research Centre using effluent from fish-ponds containing piggery wastes

Vegetable	Production ($t\ ha^{-1}$)
Green beans	13,4
Beetroot	12,9
Cabbage	20,2
Carrots	27,2
Cucumbers	53,4
Potatoes	26,7
Pumpkins and squash	8,8
Spinach	28,5
Tomatoes	21,1
Onions	5,4

Discussion

Specific climatic conditions of different geographical regions necessitate separate investigations into problems involved in the incorporation of animal wastes in fish polyculture systems to overcome water quality and other related problems unique to such areas. For this reason a number of projects were initiated in view of the possible commercial exploitation of integrated fish-cum-animal production systems in Transkei. Apart form the use of manure as a nutrient in fish-pond production systems, alternative feed other than high protein carp and trout formulated pellets, which have become extremely expensive in recent years, had to be considered. Vitamin-enriched chicken laying pellets (18% protein) and broiler starter mash (22% protein) appeared to be suitable alternative commercial feeds which could be investigated and adapted for nutrition of fish. Although the feed conversion ratio for this kind of food formula was found to be higher than anticipated, probably because of the lower protein content thereof, its much lower price makes it an attractive alternative to either carp or trout pellets.

Much information exists on the use of pig manure in fish production systems. In Africa, some work on the integration of pig production and fish farming has been reported where the cichlid *Oreochromis niloticus* and the African catfish *Clarias lazera* were produced in polyculture in ponds receiving pig manure (Vincke, 1976; Miller, 1976, 1977). Yields of 4 800 – 7 700 kg $ha^{-1}y^{-1}$ were obtained by these research workers, with *C. lazera* apparently feeding on wild spawns of *O. niloticus* in the ponds. In North America, Buck, *et al.* (1979) made extensive use of pig manure in fish production systems. By recycling pig manure through fish-ponds and by using fish in polyculture, fish yields of approximately 3 – 4 t $ha^{-1}y^{-1}$ were recorded. The total wastes of 39 – 66 pigs ha^{-1} of pond space were required to achieve this production. The two fish species which benefited the most from the manure treatment, were the Chinese silver and grass carps. Furthermore these authors showed that fish had a beneficial effect on the water quality of the manured ponds. Buck, *et al.* (1979) used 39 – 85 pigs ha^{-1} of pond space, and by using approximately 1 000 – 9 000 fish ha^{-1}, could obtain a maximum fish yield of 4,5 t ha^{-1} over a growing period of 170 – 197 days in the manured ponds. According to Tapiador, Henderson, Delmendo & Tsutsui, (1977) the manure of 30 – 45 pigs are used in pig fish farming practises in mainland China. In Taiwan, Chen & Li (1980) found that the manure of as much as 250 pigs can be used per hectare of fish-pond water without problems in fish-pond management. Hybrids of *Oreochromis aureus* and *O. niloticus* were used mainly in polyculture with *Lateolabrax japonicus*. The annual fish production obtained from this system amounted to 4 200 kg ha^{-1}. Woynarovich (1980) reported on the integration of pig farming with fish culture in Hungary where the manure of 80 pigs is required per hectare of fish-pond water. Fish species involved, mainly included the European common carp and the Chinese silver carp. Yields obtained by this author varied from 2,0 to 2,3 tons of fish $ha^{-1}y^{-1}$.Tan & Khoo (1980) also reported on the successful integration of pig and fish farming in Malaysia. Farming is, however, done at subsistence level with comparatively low fish yields being obtained. Experiments done by Cruz & Shehadeh (1980) using 40 – 60 pigs ha^{-1} pond space, realized fish yields which varied from 958 kg ha^{-1} to 1 950 kg ha^{-1} with daily production rates of 10,7 – 22,0 kg ha^{-1}. These figures are more in line with the results obtained during the present study where a net yield of 1,7 t ha^{-1} was obtained with a maximum daily production rate of 16,2 kg ha^{-1}.

According to the quantities of manure used in the present investigation and based on the calculation that a pig weighing 50 – 70 kg can produce an average of 3,5 kg of wet manure per day (Hopkins & Cruz, 1982), the manure of approximately 100 pigs ha^{-1} pond space was required to produce the equivalent of 1,7 ton fish ha^{-1} over a period of 175 days during the present investigation. In the ponds where manure was combined with feed, the average number of pigs required for the manure used, amounted to 83.

Although water quality conditions in both pond systems remained reasonably good despite the heavy manuring, the fish yields obtained during the present investigation where manure alone was used, as well as where manure was supplemented with feed, can certainly be improved upon. Compared with pig manure dosages employed by other authors, the quantities of manure applied in the present experiment may have been too high for local environment conditions, affecting the eventual fish production capacity of the ponds towards the end of the experiment. This in turn may also account for the eventual deterioration in feed conversion and manure used to produce 1 kg of fish as was reflected during the last 32-day phase of the production period.

One of the major reasons for the considerable decline in oxygen values in the fish-ponds during the present investigation, can be ascribed to the role of microbial activity and chemical oxygen demand associated with the high organic loads in the ponds. A factor which may also have influenced the relatively low concentration of oxygen in the fish ponds was the prolonged cloudy conditions which prevailed during the late summer months when exceptionally high rainfall conditions were experienced in Transkei. A similar situation existed for pond water pH, which may exceed 9 in the fish ponds later in the day and which coincided with increased algal activities. Parameters such as water conductivity, alkalinity and total hardness, were never exceptionally high but showed increases mainly associated with the application of agricultural lime and inorganic fertilizers to the fish-ponds. Despite the considerable loads of manure being added to the ponds, values for ammonia, nitrate, and phosphate were never so high as to reach levels which could have been harmful to the fish. The periodic release of small volumes of pond water for irrigation purposes and its replacement by freshwater, played an important role in keeping concentrations of parameters, such as nitrate and ammonia, relatively low.

One way to improve the use of animal wastes in fish production systems, lies in the anaerobic predigestion of such material. Waste material can be considerably upgraded in terms of protein content by this process (Watson, 1985). This approach should be investigated further under local conditions. Attention should also be given to a change in the relative densities of the different fish species used in favour of fishes such as the Chinese bighead, silver and grass carps, with a reduction in the numbers of the common carp in ponds where manure alone is used as nutrient. Where feed is added, the fish species ratio as followed in the present experiment (Table 2) need not be altered much. Our experience further suggests that the periodic adjustment of feed applied to the ponds, should be calculated as a percentage of the benthic-feeding common carp alone, as most of the other fish species largely use the development of natural and/or other food items in the fish-pond ecosystem as a result of manuring. For this reason, the calculated figures obtained on manure and feed conversion ratio's (MCR and FCR; Tables 3 & 4, and Figures 1 & 2), should in fact also be partially ascribed to the state of productivity of the fish-ponds.

The results obtained on vegetable production, using the nutrient-rich effluents from the manured ponds, merits further investigation into the integration of vegetable crops with pig-cum-fish production systems in Transkei and in other regions suitable for fish production in southern Africa.

Acknowledgements

The authors wish to express their sincere appreciation for the financial assistance from the DBSA, as well as the Department of Agriculture, Transkei Government, for the facilities and equipment provided by UNITRA and RAU; for the technical assistance of Mr D. Struwig of the SADF and Mrs C. Davies as well as to the pond workers at the Research Station for their help with the sampling program.

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