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Effect of using different types of organic animal manure on plankton abundance, and on growth and survival of *Tilapia rendalli* (Boulenger) in ponds

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Abstract

An experiment was conducted to evaluate the effect of using different types of organic manure on the plankton abundance, and growth and survival of *Tilapia rendalli* juveniles in ponds. Fish weighing 18.15 ± 0.44 g were stocked into 12, 20 m^2 ponds at 2 fish m^{-2} (40 fish $pond^{-1}$). There were three replicate ponds per treatment (chicken manure, cattle manure, pig manure, and no-manure as a control). After 84 days the *T. rendalli* in the chicken manure treatment were significantly larger and had higher net annual yields than those in the cattle manure, pig manure and no-manure treatments. The survival rates were not significantly different across the treatments. Significantly higher amounts of chlorophyll *a* and higher numbers of zooplankton were found in ponds fertilized with the chicken manure treatment. The overall results obtained in this study suggest that the use of chicken manure produces better results than cattle and pig manure treatments on unfertilized ponds.

Keywords: fertilization, animal manure, *Tilapia rendalli*, zooplankton, phytoplankton, stomach contents

Introduction

The use of manure in aquaculture supports the production of protein using inputs of little nutrient value to man or livestock (Wohlfarth & Hulata 1987). Inorganic fertilizers are expensive and their use by smallholder farmers may be limited (Swift 1993). Animal manures have a long history of use as a source of soluble phosphorus, nitrogen and carbon for algal growth and natural food production (Knud-Hansen 1998). Animal manure is often used in semi-intensive systems to improve the primary production of the ponds and fish growth (Boyd 1982; Colman & Edwards 1987; Diana, Schneeberger & Kwei Lin 1988; Msiska 1988; Knud-Hansen, Batterson & McNabb 1993; Edwards, Little & Yakupitiyage 1997; Nguenga, Breine, Yong, Tuagels & Ollevieer 1997; Nwachukwu 1997). Poultry and cattle manures have been tried with *Oreochromis niloticus* and *O. shiranus* in ponds and produced good results (Gupta, Ahamed, Bimbao & Lightfoot 1992; Knud-Hansen *et al.* 1993; Kamanga & Kunda 1998). Pig manure has been tried in aquaculture in many areas (Boyd 1982; Hepher & Pruginin 1982). However, use of organic manure in integrated systems remains poorly developed in many parts of Africa, including Malawi, as opposed to South East Asia where it is well developed (Edwards & Pullin 1990; Pullin & Prein 1995).

The various types of manure have been found to influence the natural productivity of the pond differently in terms of abundance and prevalence of phytoplankton and zooplankton as well as the benthic materials found in ponds. Boyd (1982) reported that poultry manure triggers more production of phytoplankton in ponds than any organic fertilizers including chemical fertilizer. However, traditionally not many fish farmers utilize this cheap resource. This is due to the fact that fish farming is not a primary activity of the farmer in many parts of Malawi

(Brummett 1998). Fish farming is used as a means of supplementing the family income and/or for home consumption (Brummet 1995; Brummett & Noble 1995a). Although the World Bank (1988) reported that there is a good number of livestock available that can produce manure for aquaculture in Malawi, the technology is under-utilized and their effect on production of fish in aquaculture remains unexplored. Inadequate pond inputs, both quality and quantity, has been identified as one of the key factors limiting production in small-scale aquaculture. The use of organic manure can be a good option for small-scale farmers. The aim of this study was to determine the effect of different types of manure on the growth and survival of *Tilapia rendalli*.

Materials and methods

Experimental facilities and set up

This experiment was carried out in ponds at the Bunda College fish farm, a facility of the Department of Aquaculture and Fisheries Science. Twelve concrete ponds measuring 20 m^2 (5 × 4 m) and 1.1 m deep were prepared by laying about 10 cm of soil (clay-loam) at the bottom to act as a substrate for the growth of primary production and to simulate an earthen pond. Ponds were filled with water from a nearby dam. Four treatments; chicken, pig, cattle manure and no-manure as a control, were assigned to ponds at random in a completely randomized design (CRD) and each was replicated three times.

Fertilization regime

The ponds were fertilized 2 weeks before the fish were stocked into ponds, to ensure that production of plankton and other organisms occurred. Application was done once a week by broadcasting at the following rates: chicken manure at 500 kg ha^{-1} week^{-1}, pig manure at 500 kg ha^{-1} week^{-1} and cattle manure at 1 200 kg ha^{-1} week^{-1} based on previous work (Hepher & Pruginin 1982; Gupta *et al.* 1992; Green & Boyd 1995; Sikawa 1998).

Biochemical analysis of organic manure used

The manures were analysed before application using standard methods (AOAC 1990). Analysis of dry matter was done by drying pre-weighed samples in an oven at 105 °C for about 16 h to reach a constant weight, nitrogen analysed using the Kjeldahl method, and phosphorus and potassium analysed using spectrophotometry (Table 1).

Fish stocking and sampling

Juvenile *T. rendalli* of mixed sex were collected from breeding ponds by seine net. They were kept in a large tank for a 1-week acclimation period to make sure the fish were healthy before stocking. During this time, the fish were fed maize bran. After 1 week of acclimation in the holding tank, fish were selected and stocked in each pond at the rate of 2 fish m^{-2}. The fish were allowed to acclimate to pond conditions and mortality monitored. During the acclimation period, dead fish were replaced with fish of similar size. A sample of 20 fish (50% of stocked fish) were weighed and measured. The sampling was done every 2 weeks using a seine net. The fish were anaethetised using a benzocaine solution (2 drops L^{-1}; APHA 1985) when weighing and measuring, for individual weight (g) and total length (cm). At the end of the experiment, the ponds were drained and all fish counted.

Fish growth performance

Fish performance and yield were calculated using the following formulae:

(a) Weight gain = final mean weight (g) − initial mean weight (g)
(b) Percentage increase in mean weight (%) = final mean weight − initial mean weight/initial mean weight × 100.
(c) Specific growth rate (% day^{-1}) = (log$_e$ final mean weight (g) − log$_e$ initial mean weight (g))/time × 100.
(d) Gross yield of fish ha^{-1} = harvested fish weight (kg)/unit area (ha)
(e) Net yield of fish ha^{-1} = (harvested fish weight − initial fish weight)/unit area (ha)
(f) Survival rate (%) = (initial number of fish − number of dead fish)/initial number of fish × 100
(g) Faulton's condition factor = weight (g)/length^3 × 100.

Table 1 Proximate composition (%) of the organic manure applied in experimental ponds (dry weight) (Mean ± SD)

Proximate component (%)	Organic manure source		
	Chicken	Pig	Cattle
Dry matter*	90.35 ± 1.65	90.02 ± 0.11	89.24 ± 0.71
Nitrogen	1.23 ± 0.07	1.20 ± 0.01	0.69 ± 0.02
Phosphorus	1.39 ± 0.05	1.32 ± 0.01	0.51 ± 0.01
Potassium	0.61 ± 0.02	0.60 ± 0.01	0.51 ± 0.01

*Wet weight.

Plankton monitoring and enumeration

Plankton was monitored in all ponds. Zooplankton was enumerated once a week by passing 50 L of pond water through a nylon plankton collecting net (100 μm). The pond water was collected from five positions around the pond using a 10 L bucket. The samples were then collected in bottles and fixed with two to four drops of 10% formalin solution. The organisms were concentrated in a 100 mL centrifuge tube from which sub-samples of 1.0 mL were taken for counting on a Sedgewick-rafter counting chamber mounted on a microscope at × 40magnification (APHA 1985; Brummett 2000). Zooplankton per litre was enumerated and categories included copepods, cladocerans (daphnia and moina) and rotifers (lecane and brachioni). The phytoplankton samples were also collected once a week and quantified as chlorophyll *a* ($\mu g\,L^{-1}$) (APHA 1985).

Chemical composition of the fish and zooplankton

A random sample of 20 fish was taken before the start of the experiment. The fish were killed, weighed and dried. They were then ground and passed through 0.2 mm mesh before being assayed for moisture, crude protein, crude fat, ash and gross energy using standard methods (AOAC 1990). At the end of the experiment, fish and zooplankton from the various treatments were also assayed for proximate body composition.

Stomach contents analysis

At the end of the experiment, a sample of six fish was taken from each treatment. The fish were dissected, and stomachs removed and stored in 10% formalin solution. The stomachs were weighed, dissected and the constituent food items separated, enumerated under light microscope and weighed (Hyslop 1980; Bubinas & Lozys 2000; Meschiatti & Arcifa 2002). Plant fragments were differentiated from detritus on the basis of colour, shape and cell structure. Differentiation of plankton and detritus was based on subjective indicators such as physical integrity. The stomach contents were grouped as detritus, higher plant, phytoplankton, zooplankton (Brummett 2000), insects and 'others' category that could not be well identified. The numerical percentages of the total particles in the stomach content were calculated based on weight (Bubinas & Lozys 2000).

Pond sediments analysis

Pond bottom soils were collected once a month during this experiment to assess organic matter loading. A soil sampler was constructed using locally available tins of about 10 cm in diameter. A hole was cut at the end to allow water to escape when sampling (Brummett 2000). The cup was pushed down into the sediments at random from two positions in the pond. The organic matter content was determined using the dry ash method (Boyd 1995). Sediments were dried at 105 °C, pulverized, sub-sampled, weighed and ignited in a muffle furnace at 350 °C for 8 h (Ayub & Boyd 1994). Per cent organic matter was estimated by subtracting the weight of the ash from the dry matter.

Water quality monitoring

Temperature (°C), dissolved oxygen ($mg\,L^{-1}$), pH, electrical conductivity ($\mu S\,cm^{-1}$) and salinity (‰) were measured using a multi-probe water checker (U-10 model, Horiba, Tokyo, Japan) by dipping into the water surface. Recordings were taken every day, 7 days a week, at 08:00 and 14:00 hours throughout the culture period. Secchi disk visibilities (cm), ammonia ($mg\,L^{-1}$), nitrite ($mg\,L^{-1}$), total alkalinity as $CaCO_3$ ($mg\,L^{-1}$), calcium ($mg\,L^{-1}$) and phosphorus ($mg\,L^{-1}$) were also measured once a week using standard methods (APHA 1985).

Statistical analysis

The data was first checked for assumptions for analysis of variance. The data was then subjected to analysis of variance (ANOVA) using a general linear model (GLM), repeated measures design on weight measurements with time. One-way ANOVA analysis was then performed at each time for weight; and other data collected to determine significance. If significant ($P<0.05$) differences were found in the ANOVA test, Duncan's multiple range test (Duncan 1955) was used to rank the groups. The data are presented as mean SE or otherwise stated, of three replicate groups. All statistical analyses were carried out using SPSS program, 10.0 (SPSS, 1999).

Results

Growth of fish

The mean weight (g) of fish started showing significant differences (ANOVA, $F_{3,236} = 5.878$, $P<0.001$) at

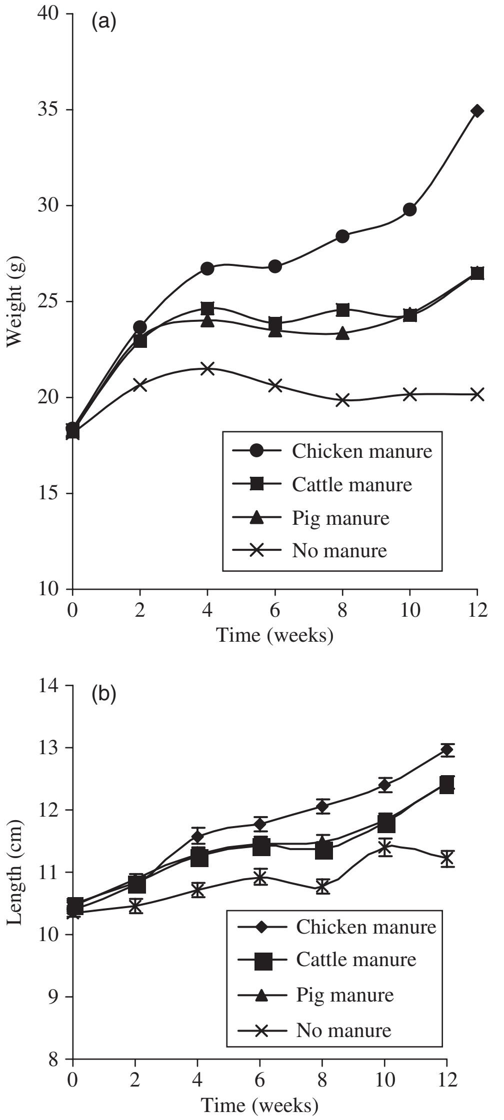

Figure 1 Mean (± SE) of weight (a) and total length (b) over time of *Tilapia rendalli* grown in ponds fertilized with different organic manure.

the initial sampling, 2 weeks after stocking (Fig. 1). The initial mean weights ranged from 18.14 to 18.38 g and were not significantly different (ANOVA, $F_{3,236} = 1.743$, $P = 0.159$). Significant differences among the treatments continued to the end of the experiment, where fish in the chicken manure treatment had significantly higher final mean weights (34.94 g) compared with cattle and pig manure with final mean weights of 26.47 and 26.50 g, respectively. However, fish in the no-manure treatment showed a significantly lower mean weight throughout the experiment with a final mean weight of 20.16 g. The weight of fish in the cattle and pig manure was not significantly different throughout the experiment (Fig. 1).

Fish in the chicken manure treatment also showed significantly (ANOVA, $F_{3,236} = 58.539$, $P < 0.001$) higher specific growth rates (0.77% day^{-1}) than the fish in the other treatments. Specific growth rates of fish in the cattle (0.42% day^{-1}) and pig manure (0.43% day^{-1}) treatments did not differ significantly. However, fish in the no-manure treatment exhibited significantly lower growth rates (0.13% day^{-1}) (Table 2).

This trend was also true for weight gains per day ranging from 0.03 g day^{-1} for no-manure treatment to 0.20 g day^{-1} for chicken manure treatment; percent increase in weight ranging from 15.2% for no-manure treatment to 94.5% for chicken manure (Table 2).

Yield, condition and survival of fish

The chicken manure treatment had a significantly higher (ANOVA, $F_{3,236} = 96.259$, $P < 0.001$) gross yield (681.4 kg ha^{-1}), net yield (314.8 kg ha^{-1}) and annualised net yield (1 255 kg ha^{-1}year^{-1}) than other treatments (Table 3). Annual net yields produced from cattle (583 kg ha^{-1}year^{-1}) and pig (608 kg ha^{-1}year^{-1}) manure treatments were not significantly different. Annual net yields from the no-manure treatment (162 kg ha^{-1}year^{-1}) were significantly lower than the rest of the treatments (Table 3). Survival was not significantly (ANOVA, $F_{3,236} = 0.099$, $P = 0.958$) different from each other and the condition of the fish did not change throughout the experiment (Table 3).

Fish body composition

Moisture, ash, fat, protein and gross energy were significantly ($P < 0.05$) different among treatments (Table 4). Moisture levels differed significantly (ANOVA, $F_{4,34} = 37.969$, $P < 0.001$) among treatments with the lowest in the initial sample (64.1%) and in the no-manure (64.3%) treatment, and did not differ significantly ($P < 0.05$) from each other. Fish cultured in the pig manure treatment had significantly higher moisture than fish in no-manure treatment and initial sample. Body moisture content of fish cultured in chicken (66.8%) and cattle (67.2%) manure were the highest and did not differ significantly from each other (Table 4). Ash content decreased while fat and gross

Table 2 Initial weight, final weight, weight gain, weight gain per day, weight increase, and specific growth rate (SGR) of *Tilapia rendalli* reared in ponds fertilized with different types of organic manure (mean ± SE)*

	Treatment				
Parameter	**Chicken manure**	**Cattle manure**	**Pig manure**	**No manure**	***P*-Value**
Initial wt (g)	18.38 ± 0.26	18.31 ± 0.26	18.23 ± 0.25	18.14 ± 0.27	0.159
Final weight (g)	34.94 ± 0.43^{c}	26.47 ± 0.67^{b}	26.50 ± 0.66^{b}	20.16 ± 0.69^{a}	<0.001
Weight gain (g)	16.56 ± 0.48^{c}	8.16 ± 0.78^{b}	8.27 ± 0.68^{b}	2.53 ± 0.69^{a}	<0.001
Weight gain day^{-1}	0.20 ± 0.01^{c}	0.10 ± 0.01^{b}	0.10 ± 0.01^{b}	0.03 ± 0.01^{a}	<0.001
Weight increase (%)	94.5 ± 3.6^{c}	47.3 ± 4.9^{b}	46.7 ± 4.0^{b}	15.2 ± 4.0^{a}	<0.001
SGR (% day^{-1})	0.77 ± 0.02^{c}	0.42 ± 0.04^{b}	0.43 ± 0.03^{b}	0.13 ± 0.04^{a}	<0.001

*Values with different superscripts in a row are significantly different ($P < 0.05$).

Table 3 Gross yield, net yield, net annual yield, survival, initial and final condition of *Tilapia rendalli* in ponds fertilized with different organic manure (mean ± SE)*

	Treatment				
Parameter	**Chicken manure**	**Cattle manure**	**Pig manure**	**No manure**	***P*-Value**
Gross yield (kg ha^{-1})	681.4 ± 8.3^{c}	511.9 ± 12.9^{b}	516.7 ± 12.9^{b}	393.1 ± 13.4^{a}	<0.001
Net yield (kg ha^{-1})	313.8 ± 9.4^{c}	145.7 ± 15.1^{b}	152.1 ± 13.2^{b}	40.5 ± 13.5^{a}	<0.001
Net annual yield (kg ha^{-1})	1,255 ± 38^{c}	583 ± 60^{b}	608 ± 53^{b}	162 ± 54^{a}	<0.001
Survival (%)	97.5 ± 0.3	96.7 ± 0.4	97.5 ± 0.4	97.5 ± 0.6	0.958
Initial condition	1.64 ± 0.02^{b}	1.59 ± 0.02^{a}	1.59 ± 0.01^{a}	1.59 ± 0.01^{a}	<0.001
Final condition	1.65 ± 0.05^{b}	1.39 ± 0.04^{a}	1.39 ± 0.04^{a}	1.42 ± 0.04^{a}	<0.001

*Values with different superscripts in a row are significantly different ($P < 0.05$).

Table 4 Whole-body composition (moisture, ash, crude fat, crude protein and gross energy) of *Tilapia rendalli* in ponds fertilized with different organic manure (dry weight) (mean ± SE)*

	Proximate Component				
Treatment	**Moisture (%)**	**Ash (%)**	**Fat (%)**	**Protein (%)**	**Energy (kJ g^{-1})**
Initial	64.08 ± 0.29^{a}	14.15 ± 0.25^{d}	9.22 ± 0.08^{a}	66.68 ± 0.30^{b}	18.4 ± 0.14^{a}
Chicken manure	66.84 ± 0.08^{c}	11.26 ± 0.06^{c}	15.94 ± 0.03^{e}	70.51 ± 0.21^{c}	32.1 ± 0.09^{c}
Cattle manure	67.24 ± 0.25^{c}	9.55 ± 0.05^{b}	15.32 ± 0.07^{c}	67.86 ± 0.13^{c}	25.0 ± 0.16^{b}
Pig manure	65.35 ± 0.31^{b}	9.63 ± 0.04^{b}	15.63 ± 0.08^{d}	66.50 ± 0.26^{b}	25.0 ± 0.09^{b}
No manure	64.31 ± 0.11^{a}	9.01 ± 0.07^{a}	15.04 ± 0.06^{b}	62.97 ± 0.09^{a}	22.5 ± 0.09^{b}
P-Value	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$	$P < 0.001$

*Values with different superscripts in a column are significantly different ($P < 0.05$).

energy increased across treatments. However, protein content of the fish was variable with a decrease in pig and no-manure treatments. Fish cultured in chicken and cattle manure had the highest protein content (70.5% and 67.9% respectively) but were not significantly different from each other (Table 4).

Plankton abundance

There were significant differences in numbers among the classes of zooplankton such as copepods, cladocerans and rotifers (Fig. 2). Copepod, cladocerans (daphnia and moina) and rotifers (lecane and brachioni) numbers per liter of water sampled was significantly ($P < 0.05$) different among treatments. The no-manure treatment had significantly lower numbers of zooplankton compared with cattle, chicken and pig manure treatments. Cattle manure propagated significantly higher numbers of daphnia compared with pig manure and chicken manure. But daphnia numbers in chicken and pig manure did not differ significantly ($P < 0.05$) from each other. As far as moina was concerned, the propagation was significantly different (ANOVA, $F_{3,140} = 32.306$, $P < 0.001$)

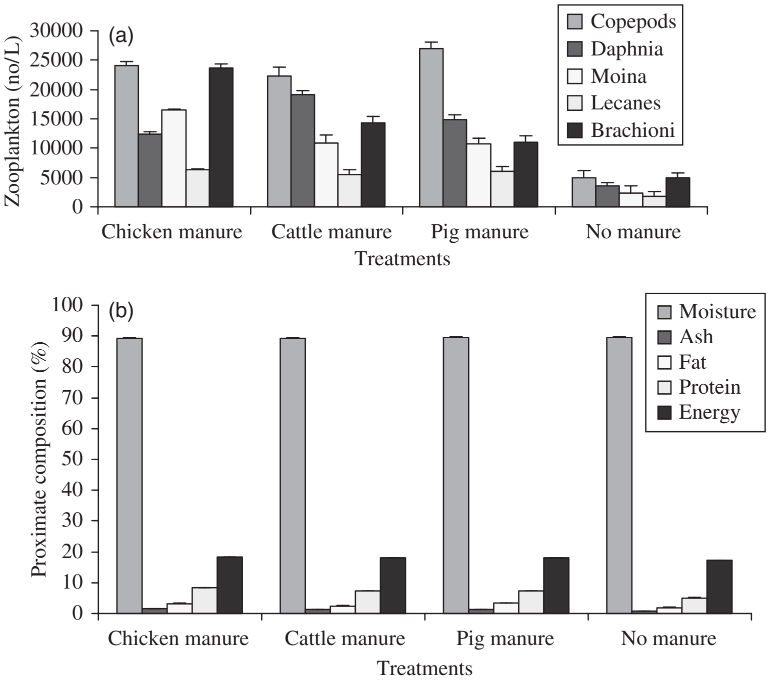

Figure 2 Mean (± SE) of population dynamics of different classes of zooplankton (a) and their proximate components (b) in ponds fertilized with different organic manure and stocked with *Tilapia rendalli*.

among treatments and was higher in chicken manure ($16\,457\,\mathrm{L}^{-1}$), with no significant differences found between the cattle ($10\,875\,\mathrm{L}^{-1}$) and pig manure ($10\,723\,\mathrm{L}^{-1}$) treatments (Fig. 2). Rotifer propagation was divided in two classes, lecanes and brachioni. Significantly (ANOVA, $F_{3,140} = 69.014$, $P < 0.001$) higher numbers of brachioni were propagated in the chicken manure treatment ($23\,649\,\mathrm{L}^{-1}$) compared with the cattle ($14\,267\,\mathrm{L}^{-1}$) and pig manure ($11\,042\,\mathrm{L}^{-1}$) treatments, which did not differ significantly from each other (Fig. 2).

Proximate composition of zooplankton

The analysis of moisture, ash, fat, protein and gross energy of the zooplankton harvested in ponds showed that the manure application had a significant effect on their body composition with the exception of moisture content. Moisture content did not differ significantly (ANOVA, $F_{3,32} = 0.742$, $P = 0.535$) among the treatments, ranging from 89.3% for cattle manure treatment to 89.6% in the no-manure treatment (Fig. 2). The ash, protein and energy contents of zooplankton differed significantly ($P < 0.05$) among the treatments and were highest in zooplankton in the chicken manure treatment. Fat content also differed significantly (ANOVA, $F_{3,32} = 322.824$, $P < 0.001$) among the treatments. The highest fat levels were found in zooplankton from the pig manure (3.4%) treatment followed by the chicken (3.3%) and cattle manure (2.5) and lastly the no-manure treatment (1.9%). Protein content also showed significant differences (ANOVA, $F_{3,32} = 660.895$, $P < 0.001$) and was higher in zooplankton from the chicken manure treatment (8.5%) and the lowest in the no-manure treatment (5.1%). The protein levels of zooplankton from cattle manure (7.3%) and pig manure (7.2%) did not differ significantly from each other (Fig. 2).

Stomach contents

The stomach contents of the fish were variable, depended on the type of manure used, and differed significantly (ANOVA, $F_{3,20} = 480.719$, $P < 0.001$). The fish from the no-manure treatment had a significantly higher amount of detritus (51.1%) in their stomachs followed by fish cultured in pig manure (41.1%), cattle manure (39.1%) and lastly those in chicken manure, which had a significantly lower amount of detritus (17.7%). Higher plant, zooplankton and phytoplankton contents in fish stomachs had significant differences among treatments and were predominant in fish stomachs from chicken manure treated ponds. The lowest amounts of phytoplankton were found in stomachs of fish from the no-manure treatment (15.9%, Fig. 3). Insects were significantly (ANOVA, $F_{3,20} = 45.467$, $P < 0.001$) higher in stomachs of fish cultured in the no-manure ponds (3.8%)

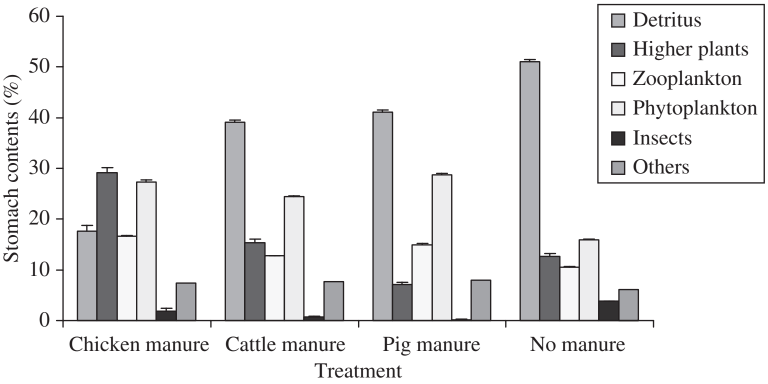

Figure 3 Mean (± SE) of stomach contents, detritus, higher plants, zooplankton, phytoplankton, insects and others of *Tilapia rendalli* in ponds fertilized with different organic manure.

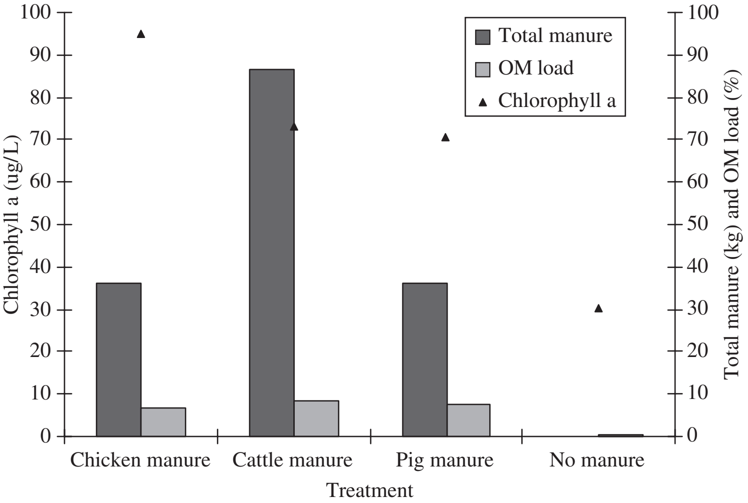

Figure 4 Relationship between organic manure applied (kg), organic matter loading (OM load) (%) and chlorophyll *a* in ponds stocked with *Tilapia rendalli* fertilized with different organic manure.

followed by chicken manure (1.9%), cattle manure (0.7%) and lastly the pig manure treatment (0.2%). Insects were not consumed in large amounts but detritus was highly consumed across treatments (Fig. 3).

Organic matter loading and chlorophyll *a*

The application of manure in ponds was expected to increase the organic matter loading. In this experiment, it was found that at the application rate of 500 kg ha^{-1} week^{-1} for chicken and pig manure, and 1200 kg ha^{-1} week^{-1} for cattle manure, the percent organic matter loading was significantly (ANOVA, $F_{3,68} = 72.134$, $P < 0.001$) different among treatments. The no-manure treatment was significantly lower (0.48%) in organic matter loading. However, organic matter loading did not differ significantly among chicken (6.68%), cattle (8.25%) and pig (7.76%) manure fertilized ponds despite the fact that cattle manure was applied at a higher rate (Fig. 4).

Phytoplankton production in the form of chlorophyll *a* indicated that chicken manure propagated significantly (ANOVA, $F_{3,140} = 56.503$, $P < 0.001$) higher amounts of chlorophyll *a* (94.9 μg L^{-1}) than cattle (72.9 μg L^{-1}) and pig manure (70.7 μg L^{-1}), which did not differ significantly from each other. The no-manure treatment had a significantly lower amount of chlorophyll *a* (30.4 μg L^{-1}, Fig. 4).

Water quality parameters

The manure application affected the quality of the water in a number of ways during this experiment. There were significant differences ($P < 0.05$) among treatments in pH, conductivity, morning and afternoon oxygen levels, ammonia, nitrite, alkalinity level, secchi disk visibilities, turbidity as well as phosphorus and potassium. However, there were no significant differences in morning and afternoon temperatures and salinity levels. The other para-

Table 5 Water quality parameters measured in ponds fertilized with different organic manure and stocked with *Tilapia rendalli* for 84 days (mean ± SE)*

	Treatment				
Parameter	**Chicken manure**	**Cattle manure**	**Pig manure**	**No manure**	***P*-value**
pH	7.63 ± 0.02^{a}	7.79 ± 0.02^{b}	7.80 ± 0.02^{b}	7.91 ± 0.02^{c}	<0.001
Conductivity (μS cm^{-1})	393 ± 3.1^{b}	438 ± 4.3^{c}	394 ± 3.5^{b}	366 ± 3.1^{a}	<0.001
Oxygen (mg L^{-1})-am	3.60 ± 0.12^{a}	4.54 ± 0.13^{b}	4.83 ± 0.15^{b}	7.48 ± 0.14^{c}	<0.001
Oxygen (mg L^{-1})-pm	11.99 ± 0.26^{b}	11.68 ± 0.25^{ab}	12.00 ± 0.22^{b}	11.06 ± 0.18^{a}	0.011
Temp (°C) – am	16.0 ± 0.01	16.1 ± 0.01	15.9 ± 0.01	16.0 ± 0.01	0.704
Temp (°C) – pm	20.9 ± 0.1	21.0 ± 0.1	20.9 ± 0.1	21.0 ± 0.01	0.810
Salinity (‰)	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	0.01 ± 0.0	0.468
Ammonia (mg L^{-1})	0.22 ± 0.01	0.23 ± 0.01	0.23 ± 0.01	0.17 ± 0.01	0.867
Nitrite (mg L^{-1})	0.02 ± 0.0	0.02 ± 0.0	0.02 ± 0.0	0.01 ± 0.0	0.346
Alkaline $CaCO_3$ (mg L^{-1})	50.8 ± 1.02^{d}	43.1 ± 0.87^{c}	40.4 ± 0.55^{b}	33.1 ± 0.35^{a}	<0.001
Phosphorus (mg L^{-1})	0.21 ± 0.0^{c}	0.20 ± 0.0^{b}	0.20 ± 0.0^{b}	0.19 ± 0.0^{a}	<0.001
Calcium (mg L^{-1})	9.37 ± 0.13^{d}	6.63 ± 0.13^{c}	5.49 ± 0.08^{b}	3.72 ± 0.18^{a}	<0.001
Secchi disk (cm)	27.2 ± 0.9^{a}	26.0 ± 0.8^{a}	25.4 ± 0.8^{a}	39.0 ± 0.3^{b}	0.034

*Values without superscript in a row are not significantly different ($P > 0.05$).

meters were within ranges for *T. rendalli* except for temperature (Table 5).

Discussion

Fish in ponds fertilized with chicken manure grew significantly better than fish in the other treatments. This result is consistent with fertilization systems where yields are above those from unfertilized ponds (Edwards, Pullin & Gatner 1988). The specific growth rates of fish in this study were significantly higher in chicken manure treated ponds. Chikafumbwa, Costa-Pierce, Jamu, Kadongola and Balarin (1993) reported low growth rates for *T. rendalli* (0.42% day^{-1}) and *Oreochromis shiranus* (0.37% day^{-1}) in ponds supplied with napier grass, *Pennisetum perpureum*. However, their results compare well with the specific growth rates in the cattle manure (0.42% day^{-1}) and pig manure (0.43% day^{-1}) teatments reported in this experiment. Chaula, Jamu, Bowman and Veverica (2002) reported 0.70% day^{-1} for *O. shiranus* in a similar input system, which was within the range of the present results, though slightly lower. Garg and Bhatnagar (2000) reported similar specific growth rates (0.71 % day^{-1}) in Indian major carp, *Cirrhinus mrigalla*, grown in ponds fertilized with a mixture of cow dung, triple superphosphate and urea. The percent increase in weight for *T. rendalli* was higher for fish in chicken manure (94.5%) in this experiment compared with those from similar systems where a 65% increase was reported for fish in ponds treated with bamboo trunks and poultry manure for *T. zilli* (Nwachukwu 1997). Yields in Sub-Saharan Africa typically range from 100–500 kg ha^{-1} year^{-1} in low input, low output systems [Hecht & de Moor (no date)]. The yields obtained in this experiment were higher than 500 kg ha^{-1} yr^{-1} in all treatments except for the no-manure treatment.

Extrapolated net yields obtained in this experiment from chicken manure (1255 kg ha^{-1} year^{-1}) were within the range of those reported by other earlier researchers in Malawi (Costa-Pierce, Lightfoot, Ruddle & Pullin 1991; Chikafumbwa *et al*. 1993, Brummett & Noble 1995b). Brooks, Dickson and Maluwa (1997) reported *T. rendalli* raised in ponds with fertilization produced net yields ranging from 1000 to 1500 kg ha^{-1} year^{-1}. The present yields are higher than reported by Chaula *et al*. (2002), which was 932 kg ha^{-1} year^{-1} for *O. shiranus* grown in ponds supplied with napier grass at 350 kg ha^{-1} week^{-1} plus urea (25 kg ha^{-1} week^{-1}).

Application of manure had a significant effect on the proximate composition of the fish indicating that the availability of food, among others, could influence the composition. The amount of protein in the present experiment is within the range reported by Yi, Kwei Lin and Diana (2002) where they fed different species of phytoplankton to sex reversed Thai red tilapia. However, they reported higher moisture (83%) and ash (23–26%) content in their study than reported in this experiment. This may be due to the species and saline environment in their experiment. Veverica, Bowman, Gichuri, Izaru, Mwau and Popma (2000) in inorganic fertilized ponds stocked with

T. niloticus and *C. gariepinus*, reported a decrease in fat content and a slight increase in moisture, protein and ash. This was in contrast to fairly high increases in fat content and a reduction in ash from the initial samples experienced in the present experiment across treatments.

Copepod propagation did not differ significantly in manure treatments and this was similar to that reported by Kamanga and Kaunda (1998). However, the differences from their report were higher numbers of copepods ($>100\,000\,L^{-1}$) than in the present experiment ($25\,000\,L^{-1}$). Cladoceran, especially daphnia, was better in the cattle manure ponds and this was consistent with work reported by Kamanga and Kaunda (1998). Moina and rotifers were more abundant in chicken manure ponds. The number of zooplankton was higher in the present experiment than reported by Brummett (2000) in an organic (napier grass) fertilization regime with *T. rendalli*. In his study, numbers were as low as $1254\,L^{-1}$ for rotifers, $76\,L^{-1}$ for copepods and $29\,L^{-1}$ for cladocerans. However, Kamanga and Kunda (1998) reported surprisingly higher numbers of copepods ($71\,030\,L^{-1}$), rotifers ($8530\,L^{-1}$) and cladocerans ($17\,972\,L^{-1}$) in no-manure treatment in concrete tanks. These variations may be due to differences in the nutrient levels in the organic manure used.

Significantly higher amounts of chlorophyll *a* were recorded in ponds fertilized with chicken manure indicating that there was a higher level of phytoplankton production. This is consistent with the work reported by Diana *et al.* (1988) with similar inputs of chicken manure ($500\,kg\,ha^{-1}\,week^{-1}$). Phytoplankton is reported to have protein levels ranging from 12% to 35%, lipids ranging from 7.2% to 23% and carbohydrates ranging from 8.2% to 8.7% on a dry weight basis. Phytoplankton is considered to also be high in ascorbic acid (Coutteau 1996). In a related study, Yi *et al.* (2002) reported high levels of ash (51–52%) in some specific phytoplankton species in ponds. The proximate analysis in the present experiment revealed that the protein and energy levels of zooplankton in chicken manure treatment were significantly higher than those from the cattle, pig and no-manure treatments. Ash content was significantly higher in the chicken manure treatment while the lowest was in the no-manure treatment. This was consistent with work reported in several studies (Watanabe 1988; Delbare, Dert & Lavens 1996).

The stomach contents of fish in this experiment ranged from detritus, higher plants, zooplanktons, phytoplankton to insects. Brummett (2000) found the same categories of stomach contents in *T. rendalli* but insects and plankton were absent in fish ranging from 21 to 40 g, which was not the case in the present experiment. It was noted in the present experiment that fish cultured in the no-manure treatment consumed significantly higher amounts of detritus followed by those in the cattle and pig manure. Fish in the ranges of 20–35 g consumed high amounts of detritus and was similar to that reported by Brummett (2000). Fish in the chicken manure ponds preferred higher plants, phytoplankton and zooplankton and reduced their intake of detritus. Insects were found least in stomachs of the fish, although those fish in the no-manure treatment had significantly higher amounts of insects in their stomachs. *T. rendalli* is believed to shift feeding habits as they grow. They change from carnivorous when young (7–33 mm) and consume lots of zooplankton, aquatic insects and detritus, which make up about 26% of their stomach contents in the wild (Meschiatti & Arcifa 2002). They are herbivorous as they grow (Brummett 2000). Detritus was one of the important stomach contents encountered during the analysis. The nutritional quality of detritus from various environments (tropical and temperate) is variable in terms of protein level, which range from 2.9% to 24.2% with good amino acid profiles (Bowen 1987).

Organic matter loading due to fertilization was significantly higher in ponds fertilized with cattle manure but did not differ significantly with chicken and pig manure treatments. The levels of loading were comparable with those reported by Boyd (1990) and Brummet (2000). It is reported that pond soils tend to acquire greater organic matter concentration than surface soils and may increase with organic fertilization (Boyd 1995). The organic matter acts as substrate for the heterotrophic production of microorganisms and protozoans in microbial food webs that can be utilized by fish to obtain the much needed nutrition through natural crops of algae, bacteria and other microorganisms in organically fertilized ponds (Geiger 1983; Boyd 1995; Moriarty 1997). The results obtained in this experiment indicated that concrete ponds function similar to earthen ponds when simulated with a layer of soil (Keshavanath, Gangadhar, Ramesh, van Dam, Beveridge & Verdegem 2002).

Water quality in this experiment varied with the type of organic manure applied but did not affect the well-being of the fish. Temperatures were low during this period as it was in the cool season in Malawi, which may have slowed the growth rates of the fish, which in turn reduced the yield. Although the temperatures were within the normal range for *T. rendalli* (13.5–36 °C) according to Philipart and Ruwet (1982), the average temperatures fell below suitable ranges of 20 and 30 °C (Maruyama 1983; Boyd & Tucker 1998). The other water parameters in the present experiment were within ranges for tilapia cultured in fertilized ponds (Jansen 1990; Prinsloo, Schoonbee & Theron 1999; Bowman, Bolivar, Jimerez & Szyper 2002; Chaula *et al*. 2002). These conditions were also conducive for growth and propagation of zooplankton, such as rotifers and cladocerans, which grow and propagate well under the conditions in this experiment (Delbare & Dert 1996).

In conclusion, the results indicated that fish in chicken manure ponds performed significantly better in this experiment. Chicken manure was able to produce more natural food to sustain the high growth rates in *T. rendalli*, which in turn increased yield. This gives an oportunity to Malawian fish farmers as poultry population in Malawi was estimated at 11.5 million in 1998 and predominantly comprised of chickens (83%) followed by pigeons (14%) and ducks (2%). Other species (1%) include turkeys, geese and currently into domestication, guinea fowls (Malawi Government 1999). The chickens are widely and equitably distributed among households of the poor and marginalized people in Malawi (Safalaoh 1997). Most farmers prefer smaller animals like chickens to bigger animals like cattle because of management issues and use them mainly as a source meat, eggs and manure that can be used for fertilizing fish ponds. Sometimes farmers are also encouraged to keep the chicken house near, or on top of, their ponds in integrated aquaculture/agriculture systems.

The differences in terms of nutrient composition between chicken, pig and cattle manure found in this study were small indicating that the chicken manure's effect could be due to particle size, although the manures were treated in the same way before application, and ability to attract microorganisms that facilitate decomposition (Boyd 1995; Moriarty 1997). However, further research may be required to look at the characteristics of these manures in terms of nutrient release in aquatic environments.

Water quality parameters were within range for the growth of *T. rendalli* except for temperature, which was lower than expected for optimal growth. However, survival was high (>90%) showing that the environment had little effect on the fish's survival during this cool season of Malawi.

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