Marine Pollution Bulletin xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Application of food waste based diets in polyculture of low trophic level fish: Effects on fish growth, water quality and plankton density

Wing Yin Mo [a], Zhang Cheng [a], Wai Ming Choi [a], Yu Bon Man [a,b], Yihui Liu [c], Ming Hung Wong [a,b,*]

[a] State Key Laboratory in Marine Pollution – Croucher Institute for Environmental Sciences, Hong Kong Baptist University and City University of Hong Kong, Hong Kong, China
[b] Department of Science and Environmental Studies, The Hong Kong Institute of Education, Tai Po, Hong Kong, China
[c] Pearl River Fisheries Research Institute, Chinese Academy of Fishery Sciences, Guangzhou 510380, China

ARTICLE INFO

Keywords:
Food waste
Polyculture
Fish feed pellets
Fish growth
Water quality
Plankton

ABSTRACT

Food waste was collected from local hotels and fish feed pellets were produced for a 6 months long field feeding trial. Three types of fish feed pellets (control diet: Jinfeng® 613 formulated feed, contains mainly fish meal, plant product and fish oil; Diet A: food waste based diet without meat and 53% cereal; Diet B: food waste based diet with 25% meat and 28% cereal) were used in polyculture fish ponds to investigate the growth of fish (grass carp, bighead and mud carp), changes in water quality and plankton density. No significant differences in the levels of nitrogen and phosphorous compounds of water body were observed between 3 fish ponds after the half-year feeding trial, while pond receiving Diet A had the highest density of plankton. The food waste combination of Diet B seems to be a better formulation in terms of the overall performance on fish growth.

1. Introduction

Hong Kong is suffering from environmental problems associated with solid waste generation. In 2011, 13,458 tonne per day of solid waste (including 3500 tonnes of food waste) was disposed at landfill sites (HKEPD, 2012). It is predicted that the existing landfills will be exhausted by 2020 if waste levels continue to increase at current levels. According to USEPA (2012), food waste is any food substance, raw or cooked, which is discarded, or intended or required to be discarded. Food wastes are the organic residues generated by the handling, storage, sale, preparation, cooking, and serving of foods. As dumping food waste into landfills will definitely shorten the lifespan of the existing landfill sites in Hong Kong, making use of food waste for farming fish may ease part of the pressure in disposing waste in landfills.

Currently in Hong Kong, fish farms are engaged in polyculture (grass carp, bighead carp, common carp and silver carp, mud carp in combination with tilapia or grey mullet), which is the dominated farming practice (98%) adopted by local inland fish farmers (AFCD, 2012). Local fishpond farmers preferred using cheaper materials such as livestock manure and agricultural residues and seldom used crab meal, fish meal or dried milk commonly used in some European countries (Fung, 1965). Traditionally, poultry and swine waste, food waste and agriculture waste are used in polyculture ponds as feed stuff (Lau et al., 2003; Wong et al., 2004). Examples of unconsumed food or agricultural by-product used by local fish farmers for feeding fish are rice bran, wheat bran, peanut cake, bread, expired instant noodles or leftover from household kitchens. Moreover, manure from animals has been used. In the past, animals such as pigs and ducks are reared along with fish, as input of manure provide nutrients as pond fertilizer by providing nitrogen and phosphorous that support growth of planktons. Plankton biomass will in turn serve as food for fish in fish ponds for filter feeder (Wong et al., 2004), such as bighead carp. However, the growth performance of fish in waste-fed culture ponds is generally inferior to fish in compound diet-fed ponds as compound diets are made up with nutritious ingredients such as fish meal, fish oil and oilseed and are designed to meet the nutrient requirements of fish.

Local fish farmers tend to feed their fish a larger amount of cheaper feed to compensate the imbalance of nutrients contained in these feeds, rendering pond water highly enriched by nutrients. Fortunately, the pond water is drained periodically for fish harvesting and pond maintenance. It is commonly known that aquaculture activities would affect the water quality of the receiving water body. Although the frequency of pond drainage per pond is not high, there are 1700 ha of fish ponds located in North-western and North eastern Hong Kong (AFCD, 2012) and it has been reported that pond drainage would negatively affect the biogeochemistry of benthic communities of receiving body (Rrvik et al., 1994). As the untreated pond water is directly discharged to water channels nearby, the sudden increase in nutrients might seriously affect the nearby habitats such as mangroves. It is essential to investigate the nutritional profile of the fish feed as well as their impacts on water quality of pond water.

* Corresponding author at: State Key Laboratory in Marine Pollution – Croucher Institute for Environmental Sciences, Hong Kong Baptist University and City University of Hong Kong, Hong Kong, China.
E-mail address: mhwong@hkbu.edu.hk (M.H. Wong).

0025-326X/$ - see front matter © 2014 Published by Elsevier Ltd.
http://dx.doi.org/10.1016/j.marpolbul.2014.01.020

Based on the historical success in using waste material for inland fish farming, the use of food waste to produce fish feed pellets was investigated. However, to our best knowledge, there is a lack of information on the use of kitchen leftover on fish growth or water quality. It was hypothesized that farming different species of low trophic level carps using food waste based diets would be beneficial in fully utilizing the residual energy contained in the food waste, as different fish species possess different feeding habits. The objectives of the present study were to investigate (1) the effects of food waste based diets on water quality and plankton density; and (2) the growth performance of fish fed with food waste based diets.

2. Materials and methods

2.1. Fish diets

Food wastes were collected from local hotels which mainly consisted of food processing waste and partly post consumed waste, which were then classified into 4 major categories; fruit peel and vegetables, meat, bone meal and cereal wastes. Detailed diet composition of the 2 food waste based fish feed pellets (Diet A and Diet B) are listed in Table 1. Fruit waste contained mainly peels with some flesh of various fruits, about 25% of pineapple, 25% watermelon, 15% Cantaloupe, 35% others e.g. strawberry, banana, and apple. Meat wastes included 60–70% of beef, pork and chicken, 30–40% of fish such as salmon and groupers. Vegetables were various types of leaf vegetables, such as lettuce and spinach. Cereals usually included rice bran, soy bean meal, rice grain and spaghetti. Briefly, individual ingredients were chopped and surplus water was removed by a squeezing machine. After drying for 6 h, the dried food waste was powdered and different ratio of food waste powders were mixed with raw materials such as starch and fish meal for making fish feed pellets. Food waste made up for 75% weight of the final fish feed pellets. Prepared diets were then stored in a dry indoor room. Jinfeng® 613 formulated feed was used as control fish feed pellets, which contains mainly flour, wheat middling, fish meal, rapeseed meal, bean pulp, bean oil and fish oil. Amino acid contents of the 3 fish diets were listed in Table 2.

2.2. Fish ponds, fish and feeding trial

A 60 year-old abandoned fish pond (around 1300 m^2) at Tong To Tsuen in Sha Tau Kok owned by Sha Tau Kok Farm (Organic) Company Limited was used for the field trials in the present study. Three rectangular-shaped fish ponds with about 400 m^2 in surface area (18 m × 22 m) and 3 m in depth were dug during the summer of 2011. U-shaped pipes were installed in each pond to collect to a nearby river for water trapping and draining. The fish ponds were filled with water, which was mainly from rainfall and mountain drainage. Fries of grass carp (*Ctenopharyngodon idella*), bighead carp (*Hypophthalmichthys nobilis*) and mud carp (*Cirrhinus molitorella*) were purchased from mainland China. One thousand fish were stocked at each fish pond with grass carp:bighead:mud carp ratio at 3:1:1. Feeding trial commenced on October, 2011 and finished on April, 2012. Each pond was fed daily with one of the experimental diets and fish were fed at a fixed feeding rate of 4% body mass (W/W) of grass carp twice a day at 9:00 am and 4:30 pm manually. Wet weight gain, length gain and productivity of fish were monitored for all 3 species of fish and the weight and length of at least 10 fish of each species from each pond were collected by netting and measured at the end of feeding trial. Productivity of fish was estimated by the following equation according to William (1992):

$$\text{Productivity (kg fish/ha)} = \text{Fish weight (kg)} \times \text{no. of individuals} / \text{pond area (ha)}$$

In addition, specific growth rate (SGR), feed conversion ratio (FCR) according to Bake et al. (2009) and protein efficiency ratio (PER) was calculated according to Kaushik et al. (2004) (for grass carp only). SGR, FCR and PER were respectively calculated by the following equations:

$$\text{SGR (\%)} = [\ln \text{final weight (g)} - \ln \text{initial weight (g)}] / \text{feeding period (day)} \times 100$$

$$\text{FCR} = \text{Feed provided (g)} / [\text{final biomass} - \text{initial biomass (g)}]$$

$$\text{PER (\%)} = \text{Wet body weight gain (g)} / \text{protein intake (g)} \times 100$$

Note that uneaten food was included in the calculation as uneaten feed was not removed from fish pond.

2.3. Proximate compositions of fish diets

Total Kjeldahl nitrogen, total phosphorous, crude protein, ash content, organic content and moisture content of the 3 kinds of experimental diet were determined. Total Kjeldahl nitrogen and total phosphorous were determined following the methodology of APHA (1998). Crude protein was calculated by multiplying total Kjeldahl nitrogen by 6.25, moisture content was determined by a dry oven (105 °C for 24 h), and ash content was determined by a furnace muffler (550 °C for 4 h) (AOAC, 2000). Carbohydrate content of diets was calculated according to Castell and Tiews (1980). Energy of diet was calculated according to Stavros Chatzifotis et al. (2010). Protein solubility was calculated according to Arab and Dale (1990).

2.4. Sampling scheme and water quality monitoring

During October 2011, December 2011, February 2012 and April 2012, 3 water samples and 3 sediment samples were collected from 3 the edges each fish pond, approximately 1 m apart from the pond edge. Fish samples were collected at October 2011 and April 2012. Water quality variables, viz. dissolved oxygen (DO), pH, total alkalinity, nitrite nitrogen (NO_2–N), nitrate nitrogen

Table 1
Compositions of the food wasted based fish feed pellets.

Formulation	Food waste (% mass)					Non-food waste (% mass)	
	Fruit and vegetables[a]	Meat products[b]	Cereals[c]	Bone meal[d]	Others	Fish meal	Corn starch
Diet A	10	0	53	8	4	10	15
Diet B	10	25	28	8	4	10	15

[a] Fruit and vegetables includes pineapple, watermelon, cantaloupe, strawberry, banana, apple and leaf vegetables, like as lettuce and spinach.
[b] Meat products includes beef, pork, chicken, salmon and groupers.
[c] Cereals includes rice bran, soy bean meal, rice grain and spaghetti.
[d] Bone meals includes bone from beef, pork, chicken and grouper.

Please cite this article in press as: Mo, W.Y., et al. Application of food waste based diets in polyculture of low trophic level fish: Effects on fish growth, water quality and plankton density. Mar. Pollut. Bull. (2014), http://dx.doi.org/10.1016/j.marpolbul.2014.01.020