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Replacing fish meal by food waste in feed pellets to culture lower trophic level fish containing acceptable levels of organochlorine pesticides: Health risk assessments

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ABSTRACT

The present study used food waste (collected from local hotels and restaurants) feed pellets in polyculture of low-trophic level fish [bighead (*Aristichtys nobilis*), grass carp (*Ctenopharyngodon idellus*), and mud carp (*Cirrhina molitorella*)] aiming at producing safe and quality products for local consumption. The results indicated that grass carp (hexachlorocyclohexanes (HCHs) <0.03; dichlorodiphenyltrichloroethanes (DDTs) 1.42–3.34 ng/g ww) and bighead carp (HCHs < 0.03; DDTs 1.55–2.56 ng/g ww) fed with food waste feed pellets were relatively free of organochlorine pesticides (OCPs). The experimental ponds (water and sediment) were relatively free of OCPs, lowering the possibility of biomagnification of OCPs in the food chains within the ponds. The raw concentrations of OCPs extracted from the fish were not in the bioavailable form, which would ultimately reach bloodstream and exert adverse effects on human body. Health risk assessments based on digestible concentrations are commonly regarded as a more accurate method. The results of health risk assessments based on raw and digestible concentrations showed that the fish fed with food waste feed pellets were safe for consumption from the OCP perspective.

1. Introduction

Food waste has been a global problem and this is particularly evident in medium and high income countries and areas. The world generates around 1.3 billion ton per year of food waste, accounting for one third of all edible food produced for human consumption (Gustavsson et al., 2011). The amount of food waste generated in Hong Kong has been increasing in recent years, with the total quantity from commercial and industry sectors rising, from 400 ton per day in 2002 to 1056 ton per day in 2011. It comprised of 37% (about 330,000 ton) of the municipal solid waste loads at landfills (about 900,000 ton) in 2011 (EPD, 2011). The remaining capacities of Hong Kong's three existing landfills will run out of space by 2018 (EPD, 2011).

In modern aquaculture, aquafeeds are dependent on fishmeal as the main protein source due to its high protein content and balanced essential amino acid composition, digestible energy, minerals, and vitamins (Kaushik et al., 2004). However, fishmeal is the most expensive protein ingredient in animal and fish feeds. In addition, it has been shown that the use of trash fish as fish feeds and as ingredients of fish meal for producing pellet feeds are the major sources of pollution [mercury, polycyclic aromatic hydrocarbons (PAHs), dichlorodiphenyltrichloroethanes (DDTs), polychlorinated biphenyl (PCBs) and polybrominated diphenyl ethers (PBDEs)] (Guo et al., 2009; Suominen et al., 2011). These pollutants can be bioaccumulated and biomagnified through the food chains. Our previous studies also detected rather high concentrations of organochlorine pesticides (OCPs) in fish collected from the fish ponds located in Pearl River Delta (PRD) and fish available in Hong Kong markets (Cheung et al., 2007; Kong et al., 2005). It has been observed that the concentrations of OCPs in human tissues (e.g. milk and plasma) were significantly correlated with the frequency of fish consumption in both Hong Kong and Guangzhou populations (Wang et al., 2013; Wong et al., 2002). Some OCPs, such as DDT and its metabolites, are detrimental to the reproductive and nervous systems. Although it has not been proven that DDTs are linked with cancers in humans (Li et al., 2008), the ubiquitous presence and lipophilic properties of OCPs would facilitate their accumulation in biota and subsequent biomagnification in the food chains, leading to increased concentrations with increasing trophic levels.

Bake et al (2009) reported that a proper combination of recycled food wastes can provide necessary nutrients for fish growth, and may

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ultimately result in reductions in the level of fishmeal in aquafeeds. Therefore, using food waste feeds in polyculture of low-trophic level fish, aiming at the production of safe and quality products for local consumption, should be promoted. It is also essential to ensure that fish are cultivated with quality feed, which are relatively free of contaminants. The major objectives of the present study are to investigate: (1) the variations of OCP concentrations in the fish ponds, using food waste feeds; (2) bioaccumulation of OCPs in cultured fish with different feeding modes and (3) potential health risks based on raw and digestible OCP concentrations in fish muscle.

2. Materials and methods

2.1. Experimental design

Table S1 shows the components of food processing waste and partially post-consumption waste collected from local hotels and restaurants, used in the present study. They were classified into four major categories: vegetables and fruits, cereals, meat products, and bones. All food wastes were collected daily from the hotels and transferred to a local food waste feed pellets factory (Kowloon Biotechnology Company Limited located in Pak Lai, NT) for further processing. Individual ingredients were minced or diced into small pieces, and surplus water was removed by a squeezing machine. After drying at 80 °C for 6 h, they were grounded into powder to form different food waste products.

Different ratios of food waste products (Fig. 1) were mixed with other raw materials, such as fish meals, corn starch for pelleting fish feeds, with food wastes contributed to about 75% in the pellets, in general. The major ingredients of food waste A (FW A) were cereal food wastes e.g. rice bran, soy bean meal, rice grain and spaghetti, whereas some meat products were used to replace parts of cereals in food waste B (FW B) (Fig. 1). Commercial feed Jinfeng®, 613 formulated feed (control feed) with ~30% protein (containing mainly of wheat middling, flour, bean pulp, rapeseed meal, and fish meal, similar to FW B), is a common fish feed used in aquaculture in Pearl River Delta, including Hong Kong.

The experimental ponds (for cultivating commercial fish using food waste feed pellets) were located in Sha Tau Kok Organic Farm in Sha Tau Kok, Hong Kong. The three rectangular-shaped fish ponds (20 m × 10 m) filled up with spring water (depth: 4 m, dissolve oxygen: 3.99 mg/l, pH: 6.84) and 30% water of the ponds were refreshed once every three months for maintaining water quality, for a period of 12 months (October 2011–December 2012). The traditional fish farming model was used to culture low trophic level species fish: bighead carp (*Aristichtys nobilis*) (10–12 cm in length), grass carp (*Ctenopharyngodon idellus*) (13–16 cm), and mud carp (*Cirrhina molitorella*) (4–6 cm) (all imported from mainland China), which are more environmental friendly as they can utilize more solar energy (Wong et al., 2004). One thousand fish were stocked at each fish pond with bighead: grass carp: mud carp at the ratio of 1:3:1 (Chen et al., 2002). Grass carp mainly consumes macrophytes, and also fish feed pellets (Chen et al., 2002). Bighead carp (filter feeder) and mud carp (detritus feeder) are commonly used to maintain the pond water quality in polyculture ponds (Wong et al., 2004). Each pond was fed daily with one of the experimental diets, at a fixed feeding rate of 4–6% body weight per day for 12 months.

2.2. Sampling

During October 2011–December 2012, water, sediment and plankton samples were collected from the experimental ponds (sampling frequency: bi-monthly during the first half year and tri-monthly during the second half year). In April and December 2012, fish samples were collected from each pond. At each sampling occasion, a minimum of 10 fish were collected (to prepare homogenate of each fish species from each pond using a nylon net), with fish lengths and weights recorded. Fish samples were dissected in the field.

In order to investigate the bioaccumulation and biomagnification of OCPs in aquatic food chains of freshwater fish ponds, 3 farmed ponds located in the Guangdong Province and four abandoned ponds in Hong Kong (representing different culture models: monoculture, polyculture and abandoned ponds) were selected for comparison (Table S2). In addition, the surface sediment samples (0.5–10 cm, 3 replicates from each site) were collected using a stainless steel shovel. Samples of both sediment and fish muscle were wrapped in aluminum foil, frozen in zip-lock bags at −20 °C and transported to the laboratory until analyses.

Zooplankton samples were collected at approximately 0.5–1.0 m depth from fish ponds of each sampling site, using a non-metallic plankton net (202 μm) for multiple vertical tows. The samples were stored in 100 ml acid-treated Teflon vials (Chen et al., 2002) and transported to the laboratory. Water samples were collected from each site in precleaned amber glass bottles and acidified immediately with 4 M HCl to pH <1 and stored at 4 °C. They were then transported to the laboratory and filtered with glass fiber filters.

2.3. Determination of bioaccessibility of OCPs in Fish

The detailed procedures for determining bioaccessibility of OCPs in fish followed the method described by Moreda-Pineiro et al. (2011) and our previous study (Wang et al., 2010), with slight modifications. The entire digestion process was performed in capped Teflon centrifuge tubes (50 ml) in the dark to simulate the anaerobic condition of the stomach. Briefly, 3 g of freeze-dried fish samples was added into 30 ml of synthetic gastric juice (2.0 g/l pepsin in 0.15 M NaCl, acidified with HCl to pH 1.8) and shaken at 100 rpm for 2 h at 37 °C. Afterwards, the mixture was centrifuged (15 min, 37 °C, 1500 rpm) and the supernatant filtered through a 0.45 mm glass fiber filter. Artificial intestinal juice (30 ml, 2.0 g/l pancreatin, 2.0 g/l amylase and 5 g/l bile salts, in 0.15 M NaCl, pH 6.8) was added. Then, the mixture was resuspended and shaken at 30 rpm for 6 h at 37 °C. Finally, the tubes were centrifuged at 1500 rpm at 37 °C for 15 min to separate supernatant and solids, and the supernatant was filtered through a 0.45 mm glass fiber filter.

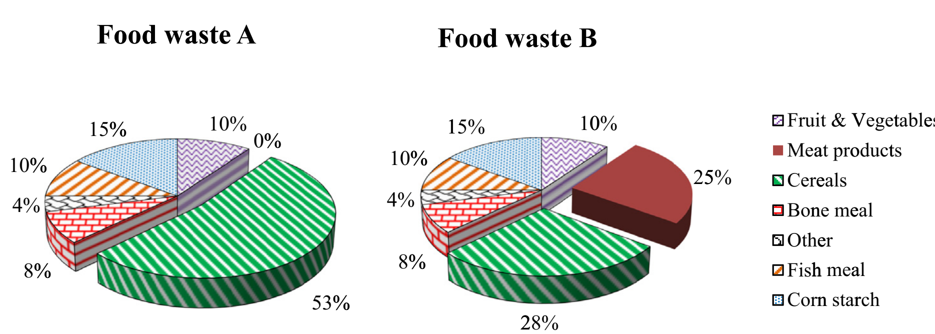

Fig. 1. Food waste fish feed formulation. Note: Each type of food waste fish feed pellets contains 75% of food waste.