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Recycle food wastes into high quality fish feeds for safe and quality fish production

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ABSTRACT

The amount of food waste generated from modern societies is increasing, which has imposed a tremendous pressure on its treatment and disposal. Food waste should be treated as a valuable resource rather than waste, and turning it into fish feeds would be a viable alternative. This paper attempts to review the feasibility of using food waste to formulate feed pellets to culture a few freshwater fish species, such as grass carp, grey mullet, and tilapia, under polyculture mode (growing different species in the same pond). These species occupy different ecological niches, with different feeding modes (i.e., herbivorous, filter feeding, etc.), and therefore all the nutrients derived from the food waste could be efficiently recycled within the ecosystem. The problems facing environmental pollution and fish contamination; the past and present situation of inland fish culture (focusing on South China); upgrade of food waste based feed pellets by adding enzymes, vitamin-mineral premix, probiotics (yeast), prebiotics, and Chinese medicinal herbs into feeds; and potential health risks of fish cultivated by food waste based pellets are discussed, citing some local examples. It can be concluded that appropriate portions of different types of food waste could satisfy basic nutritional requirements of lower trophic level fish species such as grass carp and tilapia. Upgrading the fish pellets by adding different supplements mentioned above could further elevated the quality of feeds, leading to higher growth rates, and enhanced immunity of fish. Health risk assessments based on the major environmental contaminants (mercury, PAHs and DDTs) in fish flesh showed that fish fed food waste based pellets are safer for consumption, when compared with those fed commercial feed pellets.

1. Introduction

Food waste, included raw or cooked, is any food substance which is discarded, or intended or required to be discarded (USEPA, 2012). In view of the fact that there is an increasing risk of a food crisis due to potential crop failure, food waste should be regarded as a valuable resource. Furthermore, it has been estimated that about one third of food (about 1.3 billion tonne [t]) produced word wide is wasted, and at the same time 925 million people are starving (FAO, 2015). The amount of food waste generated daily in Hong Kong has reached 3600 t, comprising of one third of the municipal solid waste (HKEPD, 2012). This will lead to rapid depletion of the limited landfill space and produce landfill gases and leachates, which are detrimental to the environment.

Therefore, food waste should be recycled as a resource for producing fuel, fertilizer and feed, which would partially ease its disposal pressure. The Organic Waste Treatment Facilities (OWTF) being built in Hong Kong, are intended to stabilize the organic waste by means of aerobic and anaerobic decomposition, to produce compost and biogas. However, the 1st phase establishment can only treat about 200 t food waste/day (HKEPD, 2012). There seems to be an urgent need to explore other alternatives for recycling and reuse of food waste.

It seems logical and feasible to turn food waste into animal feeds. However, due to the mad cow disease happened in Britain, a number of countries (including Australia, New Zealand, Canada,

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USA, and UK) have set rather straight regulations on feeding restricted animal materials (i.e., tissue or blood taken from an animal, and meal obtained from rendering tissues or blood from animals such as blood meal, meat and bone meal, fish meal, feather meal, and compounded feeds made from these products) to ruminants (Westendorf, 2000). Therefore, turning food wastes into fish feeds seem to be the best alternative.

In fact, aquaculture is gaining its importance in recent years. It produced about 3 million t of fish in the 1970s, but reached 66.63 million t by 2012, with the Asia-Pacific region continued to dominate the aquaculture sector, accounting for 88.5% of global production (FAO, 2012). However, food safety is a major public concern, especially in South China which has been developed rapidly in the past 30 years.

Fish feed accounts for more than 50% of the total cost in fish culture industry, as the costs of major feed ingredients: fish meal and cereal grains (i.e. soybean, rice bran, wheat, corn, etc.) are affected by climate, weather conditions, global economic growth and fuel costs. As a matter of fact, the costs of fishmeal, soybean meal, corn and wheat rose by 55, 67, 124, 130, and 250% respectively from 2000 to 2009, mainly due to the increasing energy cost and demand, and also higher manufacturing and transportation costs (Rana et al., 2009).

It has been estimated that by 2020, the global demand of aquaculture feed would reach 71 million t, which is doubled the figure (29.2 million t) in 2008, and almost ten-fold of 1995 production (7.6 million t). Furthermore, the aquaculture feed is mainly catered for rearing carps, accounting for 31.3% of the total feed production (FAO, 2012). The use of food wastes for fish culture would be a more sustainable strategy to reactive local fish culture industry which once prosperous during 1960s–1990s in Hong Kong.

The major aim of this presentation is to demonstrate that food wastes could be recycled into high quality fish feeds for culturing freshwater fish for producing safe and quality products, and at the same time partially ease its disposal pressure.

2. Current problems on food safety and fish contamination

2.1. Environmental pollution and food safety

Food safety is any action and policy which ensures food is safe, in the entire food chain, i.e. from production to consumption (WHO, 2013). In fact, “chemical food contaminants” is one of the 3 key global food safety concerns. The other two are “spread of microbiological hazards”, and “assessments of new food technologies (e.g., genetically modified food)”. As a matter of fact, food safety is currently one of the major public health issues in the world, especially in rapidly developing countries, due to rapid population growth, urbanization and industrialization. A wide range of persistent toxic substances (PTS) has been emitted into different ecological compartments (i.e., air, water, and soil/sediment), threatening their ability to meet safety standards, and jeopardize food production. These PTS included heavy metals and metalloids (such as cadmium [Cd], mercury [Hg], lead [Pb] and arsenic [As, a metalloid]); and persistent organic pollutants (POPs) (such as organochlorine pesticides, dioxins and flame retardants); which are widespread in the environment.

Most of these PTS share the common characteristics of being persistent (resisting biological and photo-degradation), toxic (causing adverse environmental and health problems), bioaccumulative (lipid seeking, leading to biomagnification in food chains) and capable of long-range transport through different media (reaching to remote areas, due to their semi-volatile nature, known as grasshopping effect). Some of the chemicals management issues in developing countries and countries with economy in transition have been recently reviewed (Bouwman et al., 2012). Some emerging chemicals of concern (such as bisphenol A and phthalates) recently found in contaminated fish have also become public health concerns (Wong et al., 2012). There seems to be rather concrete evidence showing the potential associations of PTS found in contaminated fish, their body loadings and health hazards of consumers.

One typical example is Hg, where the subfertile males (with abnormal seamen parameters, including inferior quantity and quality of sperms), with higher hair Hg levels significantly correlated with their frequency of fish consumption (Dickman et al., 1998). Liang et al. (2013) indicated the relationships between Hg levels in Hong Kong residents and their seafood consumption. A study revealed that human hair Hg levels collected from fish farming areas scattered around the PRD, were significantly correlated with frequency of fish consumption (Shao et al., 2013). Being neurotoxins, the high hair Hg (and very often Pb) levels are linked with higher fish consumption rates of autistic children (Ko et al., 2012).

Uncontrolled recycling of electronic waste in Guiyu (South China), has generated a wide range of toxic chemicals, including Pb, Hg, dioxins, and flame retardants (Leung et al., 2007; Wong et al., 2007), which linked with food contamination, body loadings in residents and workers, and the morbidity of major diseases (cancer, respiratory diseases, etc.) in the village (Chan et al., 2013). Our early study showed that human milk samples collected from Hong Kong and Guangzhou showed that higher concentrations of DDT, HCH and PCB detected in samples are significantly correlated to the frequency of fish consumption of the donors (Wong et al., 2002). Recently, it has been revealed that higher concentrations of heavy metals (Hg, Pb), as well as POPs (DDTs, HCHs and PCBs) detected in adipose tissues of patients with uterine leiomyomas, are also associated with their preference for seafood diets, when compared with their healthy counter parts (Qin et al., 2010). Therefore, there seems to be an urgent need to reduce human body loadings of these PTS, by lowering their concentrations in our food items, in particular fish.

2.2. Reasons of fish contamination

It is commonly observed that environmental contaminants such as Hg and DDTs can be efficiently taken up by fish, especially larger carnivorous fish (such as tuna, swordfish and shark). Fortunately, fish cultivated in inland fish ponds tend to contain lower levels of contaminants, due to less complicated trophic levels within fish ponds, and the relatively short culture periods (several months to a year) (Cheng et al., 2011, 2013). Nevertheless, consumption of contaminated fish in certain populations has become a growing public health concern in different parts of the world (Hinck et al., 2006). Furthermore, there is also a risk of contamination of aquatic products due to the use of contaminated trash fish, fishmeal and oil as feed ingredients (Dorea, 2006).

The use of trash fish for feeding carnivorous species in Asian region is a traditional practice of local fish farmers, making use of the high protein content of small fish, without much commercial value. Fish meal, largely made from trash fish, is an important component of commercial fish feed pellets. Both trash fish and fish meal provide an important source of protein and oil for most carnivorous fish and even animals, due to the unique amino acid profile, high digestibility and oil content (Huntington and Hasan, 2009). Unfortunately, it has been noted that both trash fish and fish meal available in South China (including Hong Kong) are contaminated with total and methyl Hg (Liang et al., 2011).

Maule et al. (2007) analyzed fish feeds used in US Fish and