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Use of food waste, fish waste and food processing waste for China's aquaculture industry: Needs and challenge

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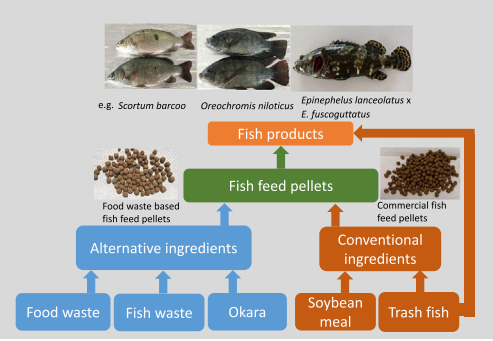
HIGHLIGHTS

- China's aquacultural industry dominates global aquaculture production
- Omnivorous and herbivorous fish are the major species cultured in China
- Conventional ingredients could be partially replaced by food waste
- Currently no laws or standards regulate the use of food waste in fish feed

GRAPHICAL ABSTRACT



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ABSTRACT

China's aquaculture industry is growing dramatically in recent years and now accounts for 60.5% of global aquaculture production. Fish protein is expected to play an important role in China's food security. Formulated feed has become the main diet of farmed fish. The species farmed have been diversified, and a large amount of 'trash fish' is directly used as feed or is processed into fishmeal for fish feed. The use of locally available food waste as an alternative protein source for producing fish feed has been suggested as a means of tackling the problem of sourcing safe and sustainable feed. This paper reviews the feasibility of using locally available waste materials, including fish waste, okara and food waste. Although the fishmeal derived from fish waste, okara or food waste is less nutritious than fishmeal from whole fish or soybean meal, most fish species farmed in China, such as tilapia and various Chinese carp, grow well on diets with minimal amounts of fishmeal and 40% digestible carbohydrate. It can be concluded that food waste is suitable as a component of the diet of farmed fish. However, it will be necessary to revise regulations on feed and feed ingredients to facilitate the use of food waste in the manufacture of fish feed.

1. Current state of aquaculture in China

The latest available statistics indicate that China has been the world's largest producer and exporter of aquaculture products in 2015, accounting for 60.5% of global aquaculture production (FAO, 2017). The ratio of fishing to aquaculture production in China was 74:26 in 1978,

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increasing to 30.3:69.7 in 2008 (Fishery Bureau of Department of Agriculture, 2009). The amount of aquatic resources captured from the environment has plateaued in the past 20 years (FAO, 2016), and it could be expected that aquaculture production will account for a larger proportion of the total fish supply in the future, as domestic fisheries are over-exploited (FAO, 2016; Mallory, 2013; Villasante et al., 2013). Fish is an important protein source and aquaculture will play an increasingly important role in future food security.

Most freshwater fish ponds in China are polyculture ponds used for carp and tilapia. The species commonly reared in polyculture ponds include omnivorous fish such as common carp (*Cyprinus carpio*), crucian carp (*Carassius* spp.) and tilapia (*Oreochromis* spp.), herbivorous fish such as grass carp (*Ctenopharyngodon idella*) and filter-feeding fish such as silver carp (*Hypophthalmichthys molitrix*) and bighead carp (*Hypophthalmichthys nobilis*). Table 1 lists the species farmed and their production volumes in 2008 and 2015. China produced over 18 million tonnes of carp and around 1.27 million tonnes of tilapia in 2015, accounting for about 90% of global carp production and about 35% of global tilapia production (FAO, 2017). The data show that omnivorous and herbivorous Chinese carp are the major species produced by China's aquaculture industry. However, the farming practices of Chinese fish farmers have changed. Previously, dyke pond systems that used waste feed (various waste materials such as animal excreta, food waste or agricultural by-products) and grass (for culturing grass carp) were popular in China (Lau et al., 2003; Prein, 2002; Wong et al., 2004). Nowadays, more and more fish farmers have adopted intensive culture methods using formulated feed pellets (Chiu et al., 2013).

Another trend is that Chinese fish farmers have diversified the fish species farmed. For example, the production of non-native species in China increased from 780,000 t in 1998 to 2.5 million tonnes in 2006, representing 5.9% and 11.7% of the total inland aquaculture production, respectively (Liu and Li, 2010). A large quantity of tilapia (worth about US$ 1 billion) produced in China is exported to the United States, mainly as frozen fillets (Liu and Li, 2010). Moreover, because of the potential for higher selling prices, an increasing number of fish farmers culture various species of grouper, such as humpback grouper (*Cromileptes altivelis*), giant grouper (*Epinephelus lanceolatus*), orange-spotted grouper (*Epinephelus coioides*) and hybrid grouper (*Epinephelus lanceolatus* × *Epinephelus fuscoguttatus*) for export. Various species of grouper are frequently consumed in luxury restaurants in Hong Kong (WWF, 2013). Furthermore, a consumer preference shift from low-value freshwater fish to high-value seafood has also been observed in China, driven mainly by rapid urbanisation and higher overall levels of income in Chinese society (Fish Site, 2012; Mao, 2011, 2013).

2. Problems associated with current aquaculture production in China

The sustainability of China's aquaculture industry is being questioned. Fishmeal is commonly used as a protein source in the diet of farmed fish and is the most expensive ingredient in formulated fish feed. The protein digestibility of good-quality fishmeal is very high, as is the amino acid availability (Anderson et al., 1995). The crude protein content of fishmeal used as feed ranges from 60% to 68% and is a good source of essential fatty acids, minerals and trace elements (Heuzé et al., 2015). China's aquaculture industry consumed approximately 1.4 million tonnes of fishmeal in 2015 (Mundi, 2016), and China has always been the largest importer of fishmeal from the global market (Cao

Table 1
Fish species farmed by Chinese fish farmers and their production volume.

Fish	Species name	Production volume in 2009** (tonnes)	Production volume in 2015** (tonnes)	Percentage change (%)	Diet preference
Freshwater					
Grass carp	*Ctenopharyngodon idellus*	4,081,520	5,676,235	39.1	Herbivorous
Silver carp	*Hypophthalmichthys molitrix*	3,484,442	4,354,638	25	Filter feeder
Bighead carp	*Hypophthalmichthys nobilis*	2,434,555	3,359,440	38	Filter feeder
Common carp	*Cyprinus carpio*	2,462,346	3,357,962	36.4	Omnivorous
Carassius spp.	*Carassius* spp.	2,055,478	2,912,258	41.7	Omnivorous
Nile tilapia	*Oreochromis niloticus*	943,478	1,334,482	41.4	Omnivorous
Freshwater fishes nei	*Osteichthyes*	489,610	601,439	22.8	Not applicable
Wuchang bream	*Megalobrama amblycephala*	625,789	796,830	27.3	Herbivorous
Black carp	*Mylopharyngodon piceus*	387,623	596,102	53.8	Omnivorous
Snakehead	*Channa argus*	358,502	495,574	38.2	Carnivorous
Amur catfish	*Silurus asotus*	325,268	450,064	38.4	Omnivorous
Blue Nile tilapia, hybrid	*Oreochromis aureus* × *O. niloticus*	314,500 F	445,000 F	41.5	Omnivorous
Asian swamp eel	*Monopterus albus*	237,034	367,547	55.1	Carnivorous
Largemouth black bass	*Micropterus salmoides*	174,471	353,081	102.4	Carnivorous
Pond loach	*Misgurnus anguillicaudatus*	176,405	366,186	107.6	Omnivorous
Yellow catfish	*Pelteobagrus fulvidraco*	163,556	355,725	117.5	Omnivorous
Mandarin fish	*Siniperca chuatsi*	235,514	298,057	26.6	Carnivorous
Channel catfish	*Ictalurus punctatus*	223,233	264,965	18.7	Omnivorous
Pirapatinga	*Piaractus brachypomus*	85,706	108,874	27	Herbivorous
Obscure pufferfish	*Takifugu obscurus*	2210		5220	Carnivorous
Total		19,276,930	26,745,454	38.7	
Marine fish					
Marine fishes nei	Osteichthyes	264,851	794,685	200	Not applicable
Large yellow croaker	*Larimichthys croceus*	66,021	148,616	125.1	Carnivorous
Japanese seabass	*Lateolabrax japonicus*	101,971	122,542	20.2	Carnivorous
Snubnose pompano	*Trachinotus blochii*	66,000 F	110,000 F	66.7	Carnivorous
Groupers nei	*Epinephelus* spp	44,155	100,006	126.5	Carnivorous
Red drum	*Sciaenops ocellatus*	49,118	71,697	46	Carnivorous
Lefteye flounders nei	Bothidae	26,672	76,837	188.1	Carnivorous
Turbot	*Psetta maxima*	60,000 F	55,000 F	−8.3	Carnivorous
Porgies, Seabreams nei	Sparidae	40,253	69,795	73.4	Carnivorous
Cobia	*Rachycentron canadum*	29,104	36,867	26.7	Carnivorous
Amberjacks nei	*Seriola* spp	19,404	20,484	5.6	Carnivorous
Tiger pufferfish	*Takifugu rubripes*	18,868	23,372	23.9	Carnivorous
Righteye flounders nei	Pleuronectidae	11,521	8618	−25.2	Carnivorous
Total		800,148	1,643,754	105.4	

**Production volume data from FAO (2017). F = FMO estimated values, nei = not elsewhere included.