Aquaculture 372–375 (2013) 97–110

Contents lists available at SciVerse ScienceDirect

Aquaculture

journal homepage: www.elsevier.com/locate/aqua-online

Effects of dietary fish and vegetable oils on the growth, tissue fatty acid composition, oxidative stability and vitamin E content of red hybrid tilapia and efficacy of using fish oil finishing diets

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ARTICLE INFO

Article history:
Received 6 September 2012
Received in revised form 25 October 2012
Accepted 26 October 2012
Available online 2 November 2012

Keywords:
Fish oil replacement
Lipid peroxidation
Crude palm oil
Soybean oil
Linseed oil

ABSTRACT

The use of alternative lipids in tilapia feeds is becoming increasingly commonplace due to the rising cost of fish oil (FO). However, since this practice will reduce the content of heath beneficial long chain polyunsaturated fatty acids (LC-PUFA) in tilapia fillets, investigations on finishing diets to enhance their nutritional value prior to harvest are increasing. A five month grow-out trial was conducted to evaluate the replacement of dietary FO with FO + crude palm oil (CPO) (1:1), linseed oil (LO) + CPO (1:1), CPO or soybean oil (SBO) on the growth performance, feeding efficiencies, body condition, fatty acid changes of the fillet/liver, fillet vitamin E content and oxidative stability of red hybrid tilapia (*Oreochromis* sp.). Diets were fed to duplicate groups of 50 fingerlings (initial weight = 19.84 ± 0.02 g) and after five months were switched to a FO-based finishing diet and measured for tissue oxidative stability and fatty acid composition every month for another three months of culture. Results showed that growth performance and feeding efficiencies were not significantly better ($P > 0.05$) for tilapia fed the FO based-diet than the alternative oil-based diets while none of the body indices or carcass/fillet yield were impacted by the dietary lipid source. Fillet vitamin E content and oxidative stability of tilapia fed the CPO or SBO diet were significantly higher than all other dietary treatments. The fatty acid composition of tilapia fillet/liver generally reflected those of the diet. Within one month of tilapia fed the finishing diet, the content of eicosapentaenoic acid (EPA, 20:5n-3), docosahexaenoic acid (DHA, 22:6n-3) and n-3/n-6 ratios rapidly increased in the fillets. After three months on the FO finishing diet, fillet DHA was not significantly different among all dietary treatments, although EPA and the n-3/n-6 ratios were still significantly lower compared to fillets from fish continuously fed the FO diet throughout the eight months. Among the tested alternative oil based-diets, tilapia previously fed the FO + CPO diet followed by the finishing diet resulted in the highest EPA, DHA and n-3/n-6 ratios, which should decrease feeding costs while improving the fillet quality of tilapia.

1. Introduction

The use of dietary alternatives to fish oil (FO) is becoming more common and incorporated at higher levels in aquaculture feeds as global FO supplies are becoming more costly and less available (Turchini et al., 2009). Tilapia are no exception to this trend where it has been estimated that dietary FO inclusion ranges between 0 and 6% in commercial diets of tilapia, depending on the country (Tacon and Metian, 2008). Generally, alternative lipids as either a complete or partial replacement to FO provide similar growth in tilapia (Bahurmiz and Ng, 2007; Ng et al., 2001; Trushenski et al., 2009). However, since these alternative lipid sources are generally deficient in the physiologically important long chain polyunsaturated fatty acids (LC-PUFA), such as eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3), the final fatty acid profile of the fillets can be negatively impacted (Bahurmiz and Ng, 2007; Karapanagiotidis et al., 2006; Szabó et al., 2011). To mitigate such deficiencies, and therefore provide a healthier product for human consumers, investigations are increasingly being conducted on the efficacy of finishing diets comprised of marine-based oils (Izquierdo et al., 2005; Senadheera et al., 2010; Thanuthong et al., 2011; Trushenski and Bosenberg, 2009; Turchini et al., 2007).

This strategy is based on feeding aquacultured animals alternative oil-based diets during their grow-out to reduce feeding costs, followed by providing marine oil-based diets prior to harvest and thus improve their LC-PUFA content. Results have shown this to be relatively effective with many fish species, although the efficacy can be based on different factors including the amount of neutral versus polar lipids (Jobling, 2003), FO inclusion level in the finishing diet (Trushenski and Bosenberg, 2009) and prior feeding history which can be highly species-specific (Senadheera et al., 2010; Thanuthong et al., 2011; Turchini et al., 2007). For example, it was shown that

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http://dx.doi.org/10.1016/j.aquaculture.2012.10.030

Murray cod, *Maccullochella peelii peelli*, fed a finishing diet had significantly higher EPA and DHA levels for those previously fed a higher α-linolenic acid (ALA, 18:3n-3) dietary content than linoleic acid (LA, 18:2n-6) (Senadheera et al., 2010). In contrast, high levels of both dietary ALA and LA reduced the efficacy of finishing diets to rainbow trout, *Oncorhynchus mykiss* (Thanuthong et al., 2011), and these findings underscore the importance of species-specific investigations to utilize the most appropriate lipid source when a finishing diet strategy is planned.

In addition to alternative lipids being cheaper, more sustainable and readily available, another beneficial characteristic is their higher resistance to lipid peroxidation (Kanner et al., 2009). This is due to LC-PUFA deficiencies, and a higher saturated fatty acids (SFA) and monounsaturated fatty acids (MUFA) content that are less prone to oxidation, but also since some plant-based oils such as soybean oil (SBO), linseed oil (LO) and crude palm oil (CPO) naturally contain high concentrations of vitamin E (Hamre, 2011; Ng and Wang, 2011). Vitamin E is a powerful antioxidant that consists of four tocopherol and four tocotrienol isomers of α, β, γ and δ, respectively, which have been shown to significantly improve oxidative stability in fish (Frigg et al., 1990; Huang et al., 2003) as well as post-harvest fillets (Ng and Bahurmiz, 2009). While vitamin E is lipid soluble and can thus be stored for prolonged periods in fat (Hamre, 2011), the persistence of their protective properties to lipid peroxidation in fish switched to a FO-based finishing diet has yet to be elucidated.

The aim of the current experiment was to investigate the effects of dietary FO, FO + CPO (1:1), LO + CPO (1:1), CPO and SBO on the growth performance, feeding efficiency, various body indices, tissue fatty acid composition, fillet oxidative stability and vitamin E content of red hybrid tilapia, *Oreochromis* sp., after five months of grow-out culture. This was followed by feeding tilapia a 100% FO-based diet over another three months and the growth performance, feeding efficiency, oxidative stability and fatty acid composition of the fillet and liver were measured to assess the efficacy of such a strategy based on their prior feeding history.

2. Materials and methods

2.1. Grow out trial

2.1.1. Experimental diets

A total of five isonitrogenous, isolipidic and isoenergetic experimental diets were formulated to contain different lipid sources, which included fish oil (FO; rich in LC-PUFA), crude palm oil (CPO; rich in SFA) or soybean oil (SBO; rich in LA, 18:2n-6) as the sole lipid source or blends of FO + CPO (1:1) or linseed oil (LO; rich in ALA, 18:3n-3) + CPO (1:1) (Table 1). Danish fish meal and soybean meal were used as the dietary protein sources. Each experimental diet was prepared and stored as previously described by Ng et al. (2000). The proximate composition of the experimental diets is shown in Table 1 and values obtained were relatively similar for all diets as formulated. Dietary crude protein and lipid content remained relatively constant at 29.6–31.5% and 10.3–10.4%, respectively. The fatty acid composition and vitamin E content of the experimental diets are presented in Tables 2 and 3, respectively. For the fatty acid composition, the FO diet had highest amount of EPA (20:5n-3), DHA (22:6n-3), arachidonic acid (ARA; 20:4n-3) and n-3/n-6 ratio, followed by the FO + CPO diet. The LO + CPO had the highest ALA content, the CPO had the highest SFA and MUFA content and the SBO diet had the highest amount of LA, PUFA and lowest n-3/n-6 ratio (Table 2). For vitamin E, the highest dietary level was found in the FO + CPO and CPO diets with the lowest in the FO diet (Table 3). All diets contained α-T, γ-T and δ-T, while only β-T was detected in the SBO diet. Meanwhile, T3 and their isomers were only detected in diets containing CPO (*i.e.* FO + CPO, LO + CPO and CPO diets) (Table 3).

Table 1
Ingredient and proximate composition (% dry matter) of experimental diets with different added lipid sources fed to red hybrid tilapia in the grow-out trial.

Experimental diets [a]					
Ingredients	FO	FO + CPO	LO + CPO	CPO	SBO
Danish fish meal	20.55	20.55	20.55	20.55	20.55
Soybean meal	30.96	30.96	30.96	30.96	30.96
Fish oil	8.00	4.00			
Crude palm oil		4.00	4.00	8.00	
Linseed oil			4.00		
Soybean oil					8.00
Others [b]	40.49	40.49	40.49	40.49	40.49
Proximate composition					
Dry matter	91.73	93.75	92.04	89.14	93.17
Crude protein	29.76	29.94	29.87	29.67	31.51
Crude lipid	10.35	10.41	10.45	10.48	10.32
Crude ash	7.77	7.72	7.69	7.61	7.96
Crude fiber	6.88	6.82	6.50	6.24	6.70
NFE [c]	45.26	45.21	45.65	45.85	43.44

[a] Fish oil (FO) was purchased from Sri Putra Trading (Kedah, Malaysia) while the linseed oil (LO) and soybean oil (SBO) were obtained from local grocery stores. Crude palm oil (CPO) was obtained from a local palm oil refinery.
[b] Others: corn starch 21.43%; carboxymethyl cellulose 1.50%; dicalcium phosphate 1.00%; α-cellulose 11.56%; composition of vitamin premix 3.00% and mineral premix 2.00% according to Ng and Wang (2011).
[c] NFE = nitrogen free extract.

2.1.2. Source of tilapia and experimental design

Red hybrid tilapia (*Oreochromis* sp.) fingerlings were obtained from a local fish hatchery (Malaysia) and acclimated in an indoor 1000-l fiberglass tank upon arrival at our laboratory for two weeks and fed commercial tilapia pellets (Cargill Ltd., Malaysia). After acclimatization, fish were weighed (mean weight ± S.E., 19.84 ± 0.02 g) and stocked into 10 round fiberglass tanks (152 cm diameter, 75 cm

Table 2
Fatty acid composition of the experimental diets (% total fatty acids) fed to red hybrid tilapia in the grow-out trial.

Experimental diets [a]					
Fatty acid [b]	FO	FO + CPO	LO + CPO	CPO	SBO
14:0	5.71	3.24	0.74	1.23	0.69
16:0	18.35	26.93	23.73	37.64	11.16
16:1n7	10.93	4.81	1.50	1.43	0.96
18:0	2.84	3.03	2.97	3.05	3.33
18:1n9	9.67	24.27	25.82	33.12	20.09
18:1n7	4.30	ND [c]	ND	ND	ND
18:2n6	5.54	10.83	14.85	13.32	48.05
18:3n3	1.11	1.30	22.32	0.82	5.78
18:4n3	1.78	1.06	ND	ND	ND
20:1n9	2.76	1.90	1.55	1.42	1.51
20:3n6	0.29	ND	ND	ND	ND
20:4n6	0.67	0.34	ND	ND	ND
20:3n3	0.11	ND	ND	ND	ND
20:4n3	0.44	0.44	0.13	0.16	0.13
20:5n3	11.38	5.69	1.05	0.98	0.88
22:1n11	4.39	2.92	1.71	1.52	1.56
22:5n6	0.09	ND	ND	ND	ND
22:5n3	1.17	0.54	ND	ND	ND
22:6n3	10.72	6.22	1.91	1.86	1.84
Total saturates	26.90	33.19	27.44	41.91	15.18
Total monoenes	32.05	33.90	30.58	37.50	24.12
Total PUFA [d]	33.31	26.41	40.25	17.14	56.68
Total n-3 PUFA	26.71	15.24	25.40	3.82	8.63
Total n-6 PUFA	6.60	11.17	14.85	13.32	48.05
n-3/n-6	4.05	1.36	1.71	0.29	0.18

[a] FO, fish oil, LO, linseed oil; CPO, crude palm oil; SBO, soybean oil.
[b] Some minor FA are not shown (18:3n6, 20:0, 20:2 and 22:2).
[c] ND = nondetectable.
[d] PUFA = polyunsaturated fatty acids.