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Acid and re-esterified rapeseed oils as alternative vegetable oils for rainbow trout diets: Effects on lipid digestibility and growth

C. Trullàs [a,*], R. Fontanillas [b], A. Tres [c], A.C. Barroeta [a], R. Sala [a]

[a] Animal Nutrition and Welfare Service (SNiBA), Department of Animal and Food Sciences, Universitat Autònoma de Barcelona, Bellaterra, 08193, Spain
[b] Skretting Aquaculture Research Center (Skretting ARC), Sjøhagen 3, Stavanger 4016, Norway
[c] Departament de Nutrició i Bromatologia-XaRTA-INSA, Facultat de Farmàcia, Universitat de Barcelona, 08028 Barcelona, Spain

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ABSTRACT

The present study aimed at evaluating the effects of dietary acid and re-esterified rapeseed oils as alternatives to native vegetable oils (VO) on growth performance and feed utilization in rainbow trout. Acid oils are a free fatty acid (FFA)-rich by-product from the refining of VO and re-esterified oils are the final product of a chemical esterification process between acid oils and glycerol. Because re-esterified oils have a high content of mono- and diacylglycerols (MAG and DAG), known for being good emulsifiers, a higher nutritive value than that of the native and the acid oils might be expected. A 72-day feeding trial where triplicate groups of rainbow trout were fed eight experimental diets formulated to contain 15% of a native, a re-esterified and an acid rapeseed oil, in addition to a 5% of fish oil (FO), was carried out. Diets with the native or the re-esterified oils blended with the acid oil were also studied. A commercial fish oil was used for the control diet. Fish fed rapeseed acid and re-esterified oil diets (RA and RE, respectively) showed high fat and total fatty acid apparent digestibility coefficients (ADC) (RA: 90.5 ± 0.3%, RE: 92.5 ± 1.0% for total fat and RA: 95.7 ± 0.1%, RE: 95.8 ± 0.2% for total fatty acids). However, the lowest total fatty acid ADC was that obtained in animals fed RA, which was significantly lower ($P < 0.05$) than that of fish fed the rapeseed native oil diet (RN: 96.7 ± 0.1%). No significant differences in final weight were obtained between fish fed RA (375.9 ± 2.9 g) and RE (381.5 ± 11.1 g) and those fed RN (393.7 ± 6.1 g), even though both values were significantly lower ($P < 0.05$) than that of fish fed the control diet (411.1 ± 3.3 g). Nonetheless, fish fed diets including blends of the rapeseed acid and the re-esterified oils (RE/RA and RA/RE) had higher final weights (392.8 ± 4.4 and 394.6 ± 1.6, respectively) than those of RA and RE, although differences were not statistically significant. Furthermore, RA and RE diets did not produce relevant changes in plasma parameters or in the morphology of liver and intestine of fish. Therefore, the inclusion of rapeseed acid and re-esterified oils along with a 5% of FO in aqua feeds does not seem to have negative effects on fat and fatty acid digestibility, growth, plasma parameter or morphology of liver and intestine in rainbow trout. However, before recommending their use, further studies regarding their effects on the final composition and quality of fillets should be carried out.

Statement of relevance: Re-esterified and acid rapeseed oils could be included in diets for rainbow trout as economically advantageous sources with no negative results in fat and fatty acid digestibility, plasma parameters and morphology of liver and intestine.

1. Introduction

There are many studies reporting the suitability of vegetable oils (VO) as an alternative to fish oil (FO) in fish feeds (Fonseca-Madrigal et al., 2005; Sun et al., 2011; Tocher et al., 2003a; Turchini et al., 2009), as they are sustainable and economically advantageous sources. VO are mainly used in both the food and the feed industries, although their use by the biofuel industry has been rising notably since the early 2000s (Gunstone, 2011). In Europe, this is especially remarkable for rapeseed, which is the predominant feedstock for biodiesel production (Haas, 2005). Thus, the competition among industries has caused an increase of grains and oilseed prices (Behr and Pérez Gomes, 2010), which in turn has led to the need of finding suitable and economically

Abbreviations: ADC, apparent digestibility coefficient(s); ADG, average daily growth; ALT, alanine aminotransferase; AST, aspartate aminotransferase; CF, condition factor; DAG, diacylglycerol(s); FCR, feed conversion ratio; FFA, free fatty acid(s); FO, fish oil; GGT, gamma-glutamyl transferase; HDL, high density lipoproteins; HSI, hepatosomatic index; LDL, low density lipoproteins; MAG, monoacylglycerol(s); MUFA, monounsaturated fatty acid(s); PUFA, polyunsaturated fatty acid(s); SFA, saturated fatty acid(s); SGR, specific growth rate; TAG, triacylglycerol(s); VLDL, very low density lipoproteins; VO, vegetable oil(s); VSI, viscerosomatic index; WG, weight gain.

* Corresponding author.
E-mail addresses: clara.trullas@uab.cat, claratruu@gmail.com (C. Trullàs).

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interesting alternatives to the commonly used VO in fish nutrition. In this regard, the interest of the feed industry for the by- and co-products generated during the crude VO processing has also been growing. Indeed, a significant amount of by-products is generated from crude oil refining processes and can be valuable feedstocks for animal feeds (Dumont and Narine, 2007). Of these products, acid oils from the chemical refining of VO, a free fatty acid (FFA)-rich by-product, were found to be quite promising for feeding uses (Nuchi et al., 2009). In rainbow trout, an apparent digestibility coefficient (ADC) of total fatty acids above 95% was obtained for a diet including rapeseed acid oil, which did not differ from that of the native oil diet, the latter referring to the unrefined and unprocessed oil produced from vegetables (Trullàs et al., 2015).

Vegetable acid oils can be chemically re-esterified with glycerol to produce the so-called re-esterified VO. These oils can have a high final content of partial acyglycerols (monoacylglyerols, MAG and diacylglyerols, DAG), amphiphilic molecules that could exert a beneficial effect on digestibility (Fregolente et al., 2009; Martin et al., 2014). Good results in fat absorption and growth performance in broiler chicks and chickens have been obtained when including re-esterified VO in diets (Vilarrasa et al., 2014, 2015). Although the digestibility of rapeseed re-esterified oil has been investigated in rainbow trout (Trullàs et al., 2015), growth performance has not yet been assessed. Fatty acid digestibility coefficients of rainbow trout fed re-esterified oils from an unsaturated vegetable source such as rapeseed did not present differences compared to those of fish fed the native oil (Trullàs et al., 2015). Even so, from the economical point of view, acid oils seem to be a more interesting alternative than re-esterified oils since the latter are approximately 100 €/t more expensive due to the added cost of the chemical esterification (Parini, personal communication). The economic viability of re-esterified oils in relation to native oils is variable since it depends on the price differential between native and acid oils, which is in turn subjected to fluctuation.

While the digestibility of acid and re-esterified oils is acceptable in rainbow trout (Ng et al., 2010; Trullàs et al., 2015), growth performance and productive parameters have not been investigated (Aliyu-Paiko and Hashim, 2012).

Thus, one of the objectives of the present study was to assess the growth performance and the feed utilization of rainbow trout fed acid and re-esterified rapeseed oils in comparison with those of fish fed the native oil. We also aimed at evaluating the partial substitution of the native and the re-esterified oils by graded levels of the more economical acid oil in order to optimize their use.

Because diet composition could induce changes in specific plasma haematological and biochemical parameters (Peres et al., 1999), the evaluation of the plasma biochemical parameters and also the morphology of liver and intestine could provide additional information on the effects of the inclusion of these alternative oils.

2. Materials and methods

2.1. Experimental diets

Experimental diets (45% protein and 21% lipid) contained the same ingredient composition except for the added lipid source (Table 1). Three different types of rapeseed oil — native (RNO), re-esterified (REO) and acid (RAO) — were included in the diets alone (single oil diets: RN, RE or RA) or blended in graded levels (diet RE/RA: 66% RE-33% RA; diet RA/RE: 66% RA-33% RE; diet RN/RA: 66% RN-33% RA and diet RA/RN: 66% RA-33% RN) in a proportion of 15%. A 5% of commercial fish oil (FO) was included in all experimental diets. A diet including only commercial fish oil (20% of the diet) was used as a control (F). Experimental oils were provided by SILO S.p.a. (Firenze, Italy) (RNO and REO) and Cargill (Schiphol, The Netherlands) (RA). The re-esterified oil (REO) was produced by SILO S.p.a. as described in Trullàs et al. (2015). Feeds were produced at the Skretting Feed Technology Plant

Table 1
Ingredient formulation and proximate composition of the experimental diets.

	Diets							
	F	RN	RA	RE	RN/RA	RA/RN	RE/RA	RA/RE
Ingredient composition (g kg^{-1})								
Wheat[a]	60	60	60	60	60	60	60	60
Wheat gluten[b]	232.8	232.8	232.8	232.8	232.8	232.8	232.8	232.8
Soya bean meal[c]	80	80	80	80	80.0	80.0	80.0	80.0
Soya protein concentrate[d]	150	150	150	150	150	150	150	150
Faba beans whole[e]	100	100	100	100	100	100	100	100
Fish meal[f]	150	150	150	150	150	150	150	150
Fish oil[g]	201.3	52	52	52	52	52	52	52
Experimental oils[h]	0	150	150	150	150	150	150	150
Yttrium premix[i]	1	1	1	1	1	1	1	1
Mineral and vitamin premix[i]	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
Proximate composition (g kg^{-1})								
Dry matter	925.7	925.9	927.9	929.9	931	928.9	926.8	927.3
Crude protein	472.2	466.1	485.1	468.2	468	466.2	471.7	474.3
Crude fat	204.1	215.7	187.7	210.4	219.5	214.3	191.9	201.4
Ash	64.2	63.3	65	70.6	67.6	65.6	65.2	68.1
Gross energy (kJ g^{-1})	22.8	22.5	22.8	22.4	22.3	22.7	22.4	22.4
Digestible energy (kJ g^{-1})[j]	20.0	19.5	19.1	20.2	18.0	20.2	19.8	19.3

Experimental diets nomenclature: F: fish oil (control diet); RN: rapeseed native oil; REH: rapeseed re-esterified oil; RA: rapeseed acid oil; RE/RA: 66% rapeseed re-esterified oil — 33% rapeseed acid oil; RA/RE: 66% rapeseed acid oil — 33% rapeseed re-esterified oil; RN/RA: 66% rapeseed native oil — 33% rapeseed acid oil and RA/RN: 66% rapeseed acid oil — 33% rapeseed native oil.
[a] Statkorn, Norway.
[b] Cerestar Scandinavia AS, Denmark.
[c] IMCOPA, Brasil.
[d] Denofa, Norway.
[e] Ceremis, France.
[f] Welcon AS, Norway.
[g] Holtermann ANS, Norway.
[h] Experimental oils.
[i] Vitamin and mineral premix, according to requirement data from NRC (2011). Trow Nutrition, The Netherlands.
[j] Values were determined by calculating the apparent digestibility coefficient (ADC) of the gross energy of diets using the formula proposed by Maynard et al. (1979), prior to multiplying this value to the gross energy of the corresponding diet.

(Aquaculture Research Center; Stavanger, Norway) as extruded pellets. Yttrium oxide (Y_2O_3) was added to the diets as an inert marker for the apparent digestibility of fatty acid determination. Nutrient composition of experimental diets was determined by standard procedures (AOAC, 2005): moisture (934.01), ash (942.05), crude protein (968.06) and crude lipid (920.39). Unsaponifiable matter was also calculated following AOAC (2005) (933.08) as a quality control. Gross energy of dried feed was determined using an adiabatic bomb calorimeter (IKA-Kalorimeter system C4000, Jankel-Kunkel, Staufen, Germany). Yttrium was analysed in accordance to Austreng and Storebakken (2000). The ingredient formulation and proximate composition of the diets are shown in Table 1.

2.2. Fish husbandry and sampling

All the procedures were conducted in accordance with the Animal Protocol Review Committee of the Universitat Autònoma de Barcelona (UAB) and following the European Union Guidelines for the ethical care and handling of animals under experimental conditions (2010/63/EU). The trial was carried out at the Skretting Italia SPA (Mozzecane, Italy) facilities. A total of 576 rainbow trout with a mean initial body weight of 101.7 ± 8.80 g were randomly distributed into 24 cylindro-conical tanks of 600 l of capacity (24 fish per tank) in an open freshwater system with a continuous water flow of 24 l min^{-1}. Water