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The potential of tomato pomace as a feed ingredient in common carp (*Cyprinus carpio* L.) diet

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ABSTRACT. Aquaculture dependency on component feed has increased attention to alternative feedstuffs for conventional ingredients such as fish meal, oil seeds and grains. The main aim of this study was to evaluate growth performance, nutrients digestibility and body composition in common carp (*Cyprinus carpio*) fed diet with different levels of tomato pomace. Four experimental diets were formulated with similar protein content: a control diet and three experimental diets with increasing tomato pomace levels (10%, 20% and 30%). Each diet was randomly assigned to triplicate 300 l tanks. Common carps with an initial weight of 16.50 ± 0.7 g were randomly distributed in the experimental tanks. The experiment lasted for eight weeks. Results showed that 10% inclusion of tomato pomace significantly increased the final weight and specific growth rate ($P < 0.05$) of common carp compared to the control diet. Feed conversion ratio and weight gain were also improved after 10% tomato pomace diet was given to the experimental fish ($P < 0.05$). Dietary addition of 10% tomato pomace also improved apparent digestibility coefficients (ADCs) of dry matter and fat ($P < 0.05$). However, protein ADC was decreased with increasing of tomato pomace inclusion ($P < 0.05$). Body composition was not influenced by the tomato pomace inclusion ($P > 0.05$). Moreover, feeding on tomato pomace elevated plasma cholesterol concentration of the common carp ($P > 0.05$). We conclude that common carp can utilize the tomato pomace up to 30% with no negative impact on growth.

Introduction

Aquaculture production has expanded substantially in recent years and reached to 63.5 million tons production in 2011 (more than one-third of total world fisheries; FAO, 2012). With such an increase in production, the demand for more efficient diets is rising (Tacon and Metian, 2008). It is predicted that total component feed production should reach to 45 million tons by 2020 to meet the demand (Tacon and Metian, 2008). Along with the increasing demand, the price of fish feed is also increasing. Today, feed and feeding are the principal operating costs of most fish farming operation (El-Sayed, 1999; FAO, 2006), which can account for 50% or more of the variable cost of most fish culture operation (Alceste and Jory, 2000). The higher price of aquafeed is often caused by shortage and rising price of fish meal (Tacon and Metian, 2008), which has been traditionally the main protein source of aquafeed. In addition, fish farms are nowadays more dependent on component feed due to intensification of aquaculture production systems (Olsen and Hasan, 2012). A review on the global use of commercial feed showed that the proportion of commercial diet used for carps reached to 50% in 2010, while it was 20% in 1995 (Tacon et al., 2011).

Nutritional research in the past decades has paid major attention to alternative protein sources for fish meal. Most experiments focused on replacement of fish meal with oil seeds and grains (Floreto et al., 2000; Lee et al., 2002; Glencross et al., 2003). Beside these products, agricultural by-products may have a potential to be used as feed ingredients in fish diet. Recent technological developments enhanced the nutritional potential of these feedstuffs in diets for fish (Davies and Gouveia, 2010). These ingredients have been used for a number of fresh water species such as Nile tilapia (*Oreochromis niloticus*; Guimaraes et al., 2008; Shelby et al., 2008; Nguyen et al., 2009), channel catfish (*Ictalurus punctatus*; Evans et al., 2005; Robinson and Li, 2008), African catfish (*Clarias gariepinus*; Nyina-wamwiza et al., 2007; Davies and Gouveia, 2008) and common carp (*Cyprinus carpio*; Hossain et al., 2001; Jahan et al., 2003; Yamamoto et al., 2007). Tomato pomace can be among the promising alternative protein and energy sources employed for monogastric animal feed industry (Mansoori et al., 2008; Peiretti et al., 2013). This ingredient has a potential for inclusion into incomplete fish diets (Nengas et al., 1995; Hotfman et al., 1997). Tomato pomace is composed of tomato skin, pulp and crushed seeds that remain after processing of tomato for juice, paste and/or ketchup. Tomato paste factories generate 70 to 75 kg of solid waste per ton of fresh tomatoes and 71% to 72% of this waste is pomace (Sogi and Bawa, 1998; Sogi, 2001). Inclusion of tomato pomace can also influence blood cholesterol due to its high fibre content (Elliott et al., 1981; Nobakht and Safamehr, 2007; Rahmatnejad et al., 2009).

While some literature is available on application of some vegetable ingredients in common carp component diet (Hossain et al., 2001; Jahan et al., 2003; Yamamoto et al., 2007), nearly no data are available mentioning the impacts of tomato pomace, as an agricultural by-product, on common carp performance and nutrient utilization. These parameters are most valuable in the development of low cost diet for commercial carp farms. Therefore, this study was conducted to evaluate growth performance, nutrients digestibility and body composition of common carp fed different levels of tomato pomace.

Material and methods

Experimental diets

Four experimental diets were formulated with similar protein content: a control diet and three tomato pomace based-diets with increasing tomato pomace levels: 10%, 20% and 30%. A commercially available tomato pomace powder was collected from a local company (Poodre Sabz Co., Sanandaj, Iran). All diets contained similar level of fish meal, but soyabean meal and wheat flour were replaced by different levels of tomato pomace to balance the experimental diets. Nutrient composition was based on the current data available for feeding common carp (Takeuchi et al., 2002). The formulation and chemical composition of the four experimental diets are presented in Table 1. All ingredients were finely ground, mixed and pelletized. A pellet size of 2 mm was used for the diets. Pellets were air-dried at 50°C and stored at –20°C until use.

Table 1. Feed ingredients and nutrients composition (% dry weight) of the four experimental diets. Each value is the mean of three sub-samples

Indices	Control	Tomato pomace, %		
		10	20	30
Ingredients				
fishmeal	25	25	25	25
soyabean meal	35	30	25	20
wheat flour	30	25	20.5	16
tomato pomace	0	10	20	30
canola oil	5	5	4.5	4
molasses	3	3	3	3
mineral premix[1]	1	1	1	1
vitamin premix[2]	1	1	1	1
Proximate composition, %				
dry matter	93.6	94.2	94.3	94.1
crude ash	7.7	7.7	7.7	7.8
crude protein	36.7	36.6	36.4	36.3
crude fat	11.7	14.9	15.7	16.4
carbohydrate	37.5	35.0	34.5	33.6

[1] mineral premix consisted of mg · kg^{-1} premix: Mn 2600, Cu 600, Fe 6000, Zn 4600, Se 50, Iu 100, Co 50, cholin chloride 100000, up to 1 kg carrier; [2] vitamin premix consisted per kg premix: IU: vit. A 1200000, vit. D_3 400000; mg: vit. E 3000, K_3 1200, C 5400, H_2 200, B_1 200, B_2 3360, B_3 7200, B_5 9000, B_6 2400, B_9 600, B_{12} 4

Experimental design and animal

Common carp with an initial weight of 16.50 ± 0.7 g were reared for eight weeks. The experiment started after ten days of acclimation to the system. Afterward, common carp were randomly distributed in groups of 17 individuals to 12 circular tanks,

Table 2. Proximate composition of tomato pomace used in the experiment

Proximate composition, %	
Dry matter	92.0
Crude protein	22.6
Crude fat	10.7
Crude ash	4.1
Crude fibre	32.5
Carbohydrate	54.6
N-free extractives	22.1

each with a volume of around 300 l. Water quality was checked twice a week, two hours after feeding. The measured parameters were: temperature, pH, oxygen and NH_4^+-N content. Almost a half of tanks water was exchanged with fresh water every day to maintain water quality. The water temperature was kept at normal range (23.5 ± 2.4°C) during the experiment. Oxygen concentration was measured in a randomly selected tank by a digital oxygen detector and always remained above 7.5 mg · l^{-1}. The water pH ranged between 7.2 to 7.6 during the experiment. Average ammonium concentration was 0.10 ± 0.05 mg·l^{-1} over the experimental period. There were four experimental diets, so four treatments in the current study.

Experimental procedure

The experimental treatments were randomly assigned to each of the 12 tanks, having three replicates (tanks) for each treatment. The fish were fed by hand three times a day at 06:00, 12:00, and 18:00. Feeding level was restricted at 2.5% of the biomass during eight weeks of the experiment. On day 56, all fish were weighed individually. Afterward, three fish were randomly selected from each tank and sacrificed using overdosed clove essence solution for analysis of body composition.

On day 56, blood sample for plasma assessments and blood parameters were also taken. The last feeding was done on day before at 24:00. From each tank, three fish were randomly selected and immediately put in anaesthesia (clove essence solution). One and half ml of blood was collected from the caudal blood vessels in all the selected fish by hypodermic syringe (containing 3 mg Na_2EDTA), shaken gently and kept at 4°C. For serum measurements, around 1 ml of the collected samples were placed in cooled, 1.5 ml plastic tubes, mixed and centrifuged at 6 000 *g* for 5 min at 4°C. After centrifugation, plasma was collected and stored at –20°C for further analysis.

Total plasma protein content was determined according to Henry (1964) and albumin was estimated colorimetrically following the method of Wotton and Freeman (1982). Globulin and albumin were subtracted from the total protein. Plasma glucose estimation was measured colorimetrically according to Trinder (1969).

A part of fresh blood samples (0.5 ml each) were used for the estimation of leucocyte and erythrocyte counts, haematocrit and haemoglobin concentrations. Red blood cell (RBC) and white blood cell (WBC) counts were estimated following the method of Schalm et al. (1975). Haemoglobin (Hb) and haematocrit (Ht) concentrations were determined as described by Barros et al. (2002).

Digestibility measurement

During the last week of the experiment, faeces were collected by pipetting from the tank bottom almost 4 h after feeding. Samples from daily faeces were pooled until desirable amount of faeces was collected. Apparent digestibility coefficients of nutrients in the diet were determined using the indicator method with Cr_2O_3 as a marker (0.6 g · kg^{-1}). Apparent digestibility (%) of nutrients is expressed as a fractional net absorption of nutrients from the diet calculated according to:

$$ADC = 1 - [(Mar._{diet}/Mar._{faeces}) \times \\ \times (Nutr._{faeces}/Nutr._{diet})] \times 100$$

where: ADC – apparent digestibility coefficient, $Mar._{diet}$ – dietary chromic oxide concentration, $Mar._{faeces}$ – faecal chromic oxide concentration, $Nutr._{diet}$ – nutrients of the diet, $Nutr._{faeces}$ – nutrients of the faeces.

Chemical analysis

Feed samples were collected and pooled at regular intervals during the experimental period and ground using a 1-mm screen before analyses. Feed, faeces and fish body were analysed for dry matter through drying samples for 4 h at 103°C until constant weight (ISO, 1983). Ash content was determined by incineration in a muffle furnace for 4 h at 550°C until constant weight (ISO, 1978). Crude protein (N × 6.25) was measured by the Kjeldahl method after acid digestion according to ISO (1979). Fat was extracted by petroleum ether extraction in a Soxhlet apparatus. Dietary fibre components were measured by the method of Van Soest as modified by Holst (1973). Carbohydrate fraction was determined as dry matter minus fat, protein and ash in feed, and nitrogen N-free extractives were calculated as dry matter minus fat, protein, ash and crude fibre.

Fish performance

There was no mortality during the course of the trail. Weight gain was determined by the difference between initial and final body weight. Feed conversion ratio (FCR) was calculated per tank from feed intake data and weight gain as: FCR = feed consumed (g) / wet body weight gain (g). Specific growth rate (SGR) was calculated from the natural logarithm of the mean final weight minus the natural logarithm of the mean initial weight divided by the total number of experimental days expressed as a percentage per day:

$$\mathrm{SGR} = 100\ (\mathrm{Ln}\ W_{\mathrm{final}} - \mathrm{Ln}\ W_{\mathrm{initial}}) \times \mathrm{days}^{-1}$$

The calculations were based on the wet weight of the diet.

Statistical analysis

Data are presented as means of each treatment with standard deviation. All data were verified for normality after transformation (ASIN). One-way ANOVA was used to determine the effects of tomato pomace on fish performance and nutrient digestibility. Orthogonal contrast test was used to compare differences between the means. For all statistical analyses, each tank was considered as the experimental unit. Differences among treatment means were considered significant when $P < 0.05$.

Results

All growth related parameters were influenced by addition of tomato pomace to the common carp diets ($P < 0.05$; Table 3). Larger estimates of final weight and SGR were observed in common carp fed diet contained 10% tomato pomace ($P < 0.05$) copared to the control diet. However, higher levels of the tomato inclusion (20% and 30%) did not change significantly final weight and SGR. Similar to final weight and SGR, FCR was improved by addition of 10% tomato pomace but this value was elevated with increasing tomato pomace content of the diets ($P < 0.05$).

Analysis of body composition showed that dietary inclusion of tomato pomace did not cause a significant difference in common carp carcass composition compared to the control diet ($P > 0.05$; Table 4).

Inclusion of tomato pomace also affected nutrient ADC of common carp ($P < 0.05$; Table 5). Protein ADC was reduced by exchanging wheat flour and soya meal with tomato pomace ($P < 0.05$). There was also an indirect relationship between tomato pomace inclusion levels and protein ADC. However, tomato pomace inclusion improved fat ADC of the common carp ($P < 0.05$). Feeding on diet containing 10% tomato pomace increased dry matter ADC of common carp ($P < 0.05$), but inclusion of higher levels did not change this parameter.

All values for blood parameters and plasma analysis are presented in Table 6. Common carp's blood parameters were not influenced by dietary inclusion of tomato pomace ($P > 0.05$). However, tomato pomace supplementation increased plasma cholesterol level ($P < 0.05$). Other plasma parameters such as glucose, total protein, albumin and triglyceride content were not affected by this inclusion ($P > 0.05$).

Table 3. Growth performance in common carp feeding of different levels of tomato pomace over 8 weeks experimental period

Growth parameters	Control	Tomato pomace, %		
		10	20	30
Initial weight, g	16.47 ± 0.03	16.53 ± 0.06	16.60 ± 0.06	16.47 ± 0.1
Final weight, g	43.23 ± 1.06^b	46.51 ± 0.76^a	43.28 ± 0.43^b	41.84 ± 0.95^b
Weight gain, %	26.76 ± 1.06^b	29.98 ± 0.8^a	26.67 ± 0.48^b	25.37 ± 1.0^b
Feed intake, g	38.27 ± 1.35	39.87 ± 1.50	40.01 ± 1.42	39.83 ± 1.30
SGR, %/day	1.72 ± 0.04^b	1.84 ± 0.03^a	1.71 ± 0.02^b	1.67 ± 0.05^b
FCR	1.43 ± 0.05^b	1.33 ± 0.04^c	1.50 ± 0.03^{bc}	1.57 ± 0.06^a

values are means of triplicate groups ± SD; means within the rows with the different letters are significantly different ($P < 0.05$); SGR – specific growth rate; FCR – feed conversion ratio

Table 4. Body proximate composition in common carp feeding on different levels of tomato pomace over 8 weeks experimental period.

Body composition	Control	Tomato pomace, %		
		10	20	30
Dry matter, %	33.12 ± 1.45	32.14 ± 0.36	31.70 ± 1.80	32.13 ± 0.65
in DM:				
crude ash	5.67 ± 0.85	6.0 ± 1.0	6.02 ± 1.0	6.02 ± 1.0
crude protein	50.40 ± 3.06	48.14 ± 3.17	43.57 ± 7.57	45.38 ± 6.68
crude fat	44.53 ± 4.08	42.91 ± 0.71	44.83 ± 1.85	45.50 ± 1.86

values are means of triplicate groups ± SD; DM – dry matter

Table 5. Apparent digestibility coefficient of nutrients of diets with different level of tomato pomace over 8 weeks experimental period

Nutrients	Control	Tomato pomace, %		
		10	20	30
Dry matter	68.60 ± 2.25^b	71.70 ± 0.90^a	68.47 ± 1.15^b	67.27 ± 1.25^b
Crude protein	92.70 ± 1.0^a	89.90 ± 0.36^b	88.03 ± 0.45^c	85.97 ± 0.55^d
Crude fat	81.08 ± 4.0^b	86.47 ± 2.04^a	90.63 ± 2.57^a	87.90 ± 1.80^a

values are means of triplicate groups ± SD; means within the rows with the different letters are significantly different at $P < 0.05$

Table 6. Blood parameters and plasma analyses in common carp feeding of different levels of tomato pomace over 8 weeks experimental period. All values are means of three replicates per tanks per treatment ± standard deviation

Blood parameters	Control	Tomato pomace, %		
		10	20	30
Red blood cells, 10^6 µl	2.08 ± 0.31	2.12 ± 0.24	2.26 ± 0.14	2.16 ± 0.24
Haemoglobin, g · dl^{-1}	10.14 ± 0.22	10.08 ± 0.19	10.10 ± 0.27	10.13 ± 0.37
Haematocrit, %	42.0 ± 1.61	42.4 ± 0.8	42.07 ± 1.53	42.53 ± 0.72
White blood cells, 10^3 µl	8797.1 ±1088.7	8481.2 ± 583.9	7792.2 ± 1415.7	7799.2 ± 581.1
Glucose, mg · dl^{-1}	90.84 ± 38.35	103.7 ± 13.19	99.11 ± 4.7	104.0 ± 0.25
Cholesterol, mg · dl^{-1}	206.7 ± 10.19^{c}	261.7 ± 2.10^{a}	232.4 ± 2.03^{b}	243.2 ± 4.81^{b}
Triglyceride, mg · dl^{-1}	212.7 ± 10.30	208.4 ± 10.26	213.4 ± 11.52	208.5 ± 8.74
Albumin, g · dl^{-1}	3.76 ± 0.44	3.72 ± 0.23	3.86 ± 0.25	3.42 ± 0.07
Plasma protein, g · dl^{-1}	4.97 ± 0.58	5.01 ± 1.12	5.36 ± 0.26	4.40 ± 0.34

means within the rows with the different letters are significantly different at $P < 0.05$

Discussion

The current results showed that tomato pomace as a feed ingredient can replace soyabean meal and/or grain in common carp feed. Higher growth was measured at 10% inclusion level whereas greater inclusions of tomato pomace did not change growth related parameters in common carp. However, this finding is not similar to that of Hotfman et al. (1997) who observed depressions in final weight and SGR in African catfish fed diet containing 44% tomato pomace compared to a fish meal based diet. Lower growth in the catfish was probably due to a lower content of fish meal in tomato diet. Nevertheless, growth performance of the common carp is very comparable to those reported previously by Hossain et al. (2001) and Nwanna et al. (2007) when legume seeds and a mixture of vegetable feedstuffs were used in common carp diet.

As fish meal proteins can be readily transformed by fish into a new fish tissue protein of similar composition (Langar, 1997), this ingredient is generally recognized as the best source of dietary protein for the most fish species. A strong positive correlation between fish meal content of the diets and SGR and final weight of catfish was observed by Hotfman et al. (1997). Replacement of fish meal by a mix of plant protein sources (75% and 100% inclusion level) decreased growth performance in juvenile rainbow trout. The reduction in growth of the rainbow trout fed diets containing high plant protein has been attributed to changes in the dynamics of white muscle growth induced by changes in white muscle gene expression (Alami-Durante et al., 2010). Accordingly, similar or even an improved growth of the common carp fed tomato pomace diets may be related to similar quantity of fish meal in the diets (Table 1).

In the current study, body protein and fat contents were not affected by dietary tomato pomace level. This result is similar to that of Hotfman et al. (1997) who observed a similar protein and fat content in the fish body when fish meal was replaced by tomato pomace in the diets. A number of previous studies showed that the amount of dietary fat influences the amount of body fat (Henken et al., 1986; Shearer, 1994; Bureau et al., 1995). However, higher levels of dietary tomato pomace, which increased diet fat content, did not influence fish body fat (Tables 1 and 4). The lack of a positive correlation between the dietary fat and body fat contents in the present investigation may be attributed to the small differences (3.2%–4.7%) of crude fat in the diets.

Inclusion of tomato pomace improved ADC of dry matter and fat, but reduced protein ADC. The low protein ADC at tomato pomace diet is in line with the results of Nengas et al. (1995) who observed very low protein ADC (20%) for tomato pulp when tested protein ADC of common feed ingredients for sea bream. Lower ADC of dry matter is probably because of an increase in digesta viscosity induced by dietary fibre in tomato pomace diets, which may bind the nutrients (Amirkolaie et al., 2005) and limit diffusion of digestive enzymes (Choct et al., 1996). On the other hand, a positive impact of dietary tomato pomace on fat ADC may have been caused by larger contents of unsaturated fatty acids in tomato seeds (Lazos et al., 1998). It seems that a better fat digestion is compensated by a lower protein digestion leading to similar growth at high-tomato (20% and 30%) diets.

Apart from negative impact of dietary fibre, other mechanisms can also explain the effect of tomato pomace on digestibility. Limited concentration of antinutritional factors in tomato may somewhat explain the lack of negative impact of this ingredient on fish performance and ADCs (except protein ADC) (Elliott et al., 1981; Squires et al., 1992). Similarly, Squires et al. (1992) indicated that the antinutritional factors present in untreated tomato cannery waste did not appreciably depress any measured growth related parameters in broiler chicken.

The influence of dietary fibre on lipid metabolism and blood cholesterol has attracted too much attention (Elliott et al., 1981; Nobakht and Safamehr, 2007; Rahmatnejad et al., 2009). There is evidence showing that tomato diet can reduce blood cholesterol in hamster (Friedman et al., 2000), rat (Prasannakumar et al., 1997) and broiler (Rahmatnejad et al., 2009). Viscous fibre is known to enhance bile acid secretion with subsequent significant losses of these acids in the faeces. This can, in turn, result in increased hepatic synthesis of bile acids from cholesterol leading to lower blood cholesterol levels (Choct, 1997; Hossain et al., 2001).

However, in this study blood cholesterol level of the carp was elevated by feeding of dietary tomato pomace. Apparently, fibre content of tomato pomace might not have affected the absorption of intestinal cholesterol reflecting in the elevated blood cholesterol. In addition, a larger fat ADC in tomato pomace diets associated with greater values of blood cholesterol may support the idea that tomato fibre does not block cholesterol absorption in the fish intestine.

Conclusions

The one consequence of growing interest in formulated diet for common carp is to raise attention to by-products based feed ingredients. The ingredient such as tomato pomace has a high potential as a feed component replacing low content protein feedstuff such as wheat flour, and/or soyabean meal. Similar growth of common carp up to 30% of tomato pomace indicates the high potential of the ingredient in omnivorous species. Nevertheless, more detail evaluation of tomato pomace characteristics is necessary to optimize the inclusion of the ingredient for proper diet formulation (e.g., least cost formulation and waste generation) in aquaculture.

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