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Environmental health enhancement by recycling poultry processing waste into protein ingredient in common carp *Cyprinus carpio* L. diets

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Abstract---This study was designed to investigate recycling poultry processing waste into protein concentrate as a step for supporting environmental health and resource sustainability, using it as a partial replacement of fish meal in diets prepared for common carp *Cyprinus carpio* L. fingerlings and explore its effect on fish growth, feeding efficiency and feed digestibility. Poultry waste was recycled into protein concentrate by a physical method, the chemical composition of this concentrate was analyzed, amino acid profile was determined, as well as the chemical composition of the prepared diets was analyzed. Four diets were prepared with substitution ratios of 0, 25, 50 and 75% of fish meal with poultry waste protein concentrate. The results showed significant differences ($P < 0.05$) between the four experimental diets in terms of weight gain, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER) and protein productive value (PPV). The treatment T3 (substitution rate of 75%) outperformed all other three treatments. No significant differences were observed between the studied treatments in the total apparent digestibility coefficients and the digestibility coefficients of different nutrients (protein, fat, carbohydrates and ash). The study concluded the possibility of partial replacement of up to 75% of fish meal with poultry waste protein concentrate in the diets intended for common carp fingerlings without any adverse effects on growth, feeding efficiency and feed digestibility of cultured fish.

Keywords---environmental health, poultry wastes, recycling, waste management, common carp.

Introduction

The wide availability of many kinds of animal wastes (fish, poultry and slaughterhouses) in unexploited large quantities, resulted in an emerging important and serious environmental problems that must be taken into consideration (Prasanthi *et al.*, 2016; Tesfaye *et al.*, 2017). Despite the pollution that may be caused by the existence and accumulation of large quantities of animal wastes which impose many environmental and health hazards, the optimal exploitation of these wastes is by recycling through applying of suitable methods to convert them into other materials more useful in many industrial, food and fodder applications, especially as they contain a high percentage of protein are of great benefit to humans and animals when manufactured (Najim *et al.*, 2014; Vineis, 2019). In addition, many of these wastes are characterized by high digestibility and high protein content, so the attention of scientists and researchers turned to finding the best methods for extracting proteins, especially unconventional protein sources using various chemical, enzymatic and physical methods, to improve their properties and produce modified protein concentrates with good functional properties that can be used in many food systems (Tefaye *et al.*, 2018). Poultry slaughterhouses dispose large quantities of wastes that can be used in industrial and fodder applications. For example, poultry wastes constitute up to 20% of the live weight of bird, while feathers constitute 8.1, blood 3.5%, and heads, legs and internal viscera may reach 15.8% (Sionkowska *et al.*, 2011).

The rapid growth in production of aquaculture sector (which reached about 47.3 million tons in 2006 and nearly 63.6 million tons in 2011) has the potential to become the main source of future supplies of table fish rather than fisheries, in addition to providing jobs and constant income for a large segment of the world's population (FAO, 2012). It is estimated that global fish production amounted to about 179 million tons in 2018 of which 156 million tons was used for human consumption, equivalent to an annual supply rate of 20.5 kilograms per capita (FAO, 2020). The production of fish culture of common carp *Cyprinus carpio* represents the main production for many years in the continents of Asia, Europe, Africa and Latin America, and it constitutes the largest sector of global fish farming in large production systems (Gatlin, 2002), because it is one of the important cultured species in many regions of the world (Davies and Gouveia, 2006). Paying attention to the economic aspect of feeding fish is an important aspect because feeding is considered as one of the costliest requirements of aquaculture, and its cost exceeds 60% of the operating costs of culture projects (Bolivar *et al.*, 2011; Salih *et al.*, 2021). Many animal and plant protein sources are used to formulate fish diets where fishmeal is one of the best and most expensive of these sources, not only locally but globally, as its price ranges between 2-3.5 times the price of soybeans, a widespread used plant protein source (Miles and Chapman, 2009). Many efforts have been made in the fields of research and aquaculture to get advantages from animal wastes for different purposes especially preparing protein concentrated to partially replace fishmeal with sustainable ingredients in fish feed, without harming fish and its growth and

give an insight into these components (Imran *et al.*, 2019; Melenchón *et al.*, 2022). Due to the high prices of fish meal and the mostly cheap price of carp, it has become necessary to search for other economical and effective sources of animal protein in order for carp culture to become economically feasible, as a result of economic pressure and other factors related to obtaining raw feed materials, in particular, it has become necessary to invest non-traditional sources to obtain low-cost protein (Jasim *et al.*, 2016; Albadran *et al.*, 2018). Protein concentrates extracted from animal wastes, such as fish meal, meat meal and blood meal contain high amounts of essential amino acids, in addition to the presence of some vitamins such as thiamine and riboflavin (Orisasona, 2018). Poultry processing waste protein is one of the most commonly used proteins in diets, and its nutritional value depends on the raw material included and manufacturing conditions (temperature, pressure and storage methods). Due to the specific manufacturing conditions in which different proteaceous raw materials are used, the produced concentrates may differ in their characteristics and nutritional value (Gindaba *et al.*, 2019). Protein concentrates made from poultry processing waste can replace imported commercial protein concentrates where some researchers used with local feed materials in fish nutrition such as Nandakumer *et al.*, (2013) who used poultry processing wastes to feed seabass *Dicentrarchus labrax* for eight weeks with acceptable results. The current study aims toward environmental health and sustainability by using the protein concentrate extracted by recycling poultry processing wastes as an alternative for expensive fish meal which is the main used source of animal protein in common carp fingerlings nutrition and to determine the optimal percentage of replacement in the diets while providing some information that is believed to contribute to the sustainability and development of the fish farming sector.

Materials and Methods

Preparation of a poultry waste protein concentrate from (PWPC)

The protein concentrate was prepared from poultry waste according to the method described in Lee *et al.* (2016), by weighing 1000 g of waste and adding 5000 ml of distilled water, placing the mixture in an electric pressure cooker for 20 minutes at a temperature of 80 ° C. At the end of the cooking period, the mixture was left to cool and transferred to mesh containers for filtering and excluding water and oil. The filtered sample was minced in an electric grinder and spread to dry at room temperature for 3 days with continuous stirring to ensure complete dryness. The product was ground by an electric grinder and passed through a sieve with 0.5 mm. holes to exclude the remaining residues (residues of feathers, bones and nails) to facilitate diet preparation. The prepared samples were the preserved in clean and dry glass containers until they are used and tests were carried out on them. The yield was calculated by dividing the weight of the obtained product by the weight of the raw material and multiplying with 100.

Amino acid profiles

Amino acid profiles were estimated according to the method described by Vidotti *et al.* (2003), using an ion exchange column and derivation of ninhydrin after the

column in the self-analyzer Visible-6 Av uv-Spd Shimadzu using the (HPLC) High performance Liquid Chromatography device.

Chemical composition of the protein concentrate

The chemical composition of poultry waste protein concentrate was estimated using the Near Infrared Analyzer Grassi *et al.* (2018)

Experimental diets

Four diets (treatments) were prepared, namely C (control) T1, T2 and T3 and by replacing the protein concentrate with fish powder with a replacement ratio of (0,25,50,75%), respectively. A standard control diet C was prepared using conventional feed materials, and the other three diets (T1, T2, T3) were prepared by replacing fish meal with protein concentrate using the same raw materials. The dry materials were mixed after being weighed, and then the oil was added, mixed well, hot water was added, and the mixture was kneaded until the mixture was homogeneous and a cohesive dough was formed.

Table (1): Dietary ingredients, proximate composition (%) and gross energy (Kcal/ 100 g) of experimental diets

Ingredient (%)	Experimental diets			
	C	T ₁	T ₂	T ₃
Fishmeal	30	22.5	15	7.5
PWPC	0	7.5	15	22.5
Soybean meal	20	20	20	20
yellow corn	16	14	12	10
wheat meal	18	18	18	18
wheat bran	9	12	15	18
Corn oil	5	4	3	2
Vitamin-mineral premix	2	2	2	2
proximate composition %				
Moisture	7.11	7.9	7.19	7.12
Protein	30.14	31.41	30.89	31.17
Lipid	9.3	8.38	9.05	9.38
Carbohydrate	42.23	41.3	41.11	41.11
Ash	11.24	11.09	11.76	11.22
Gross energy	423.41	415.07	420.80	425.34

Aquaculture System

The Recirculation aquaculture system (RAS) was used to implement the feeding experiment. The system was established in fish hatchery at the Department of Fish and Marine Resources. The system consists of iron racks each designed to include three rows, where the first and second higher rows contain two plastic aquariums each, while the lower row contains specially designed aquarium

divided into three sections. The first section contains sponge and brocade for the purpose of depositing wastes and solid feed residues. It contains an electric heater to maintain the water temperature constant during the experiment. The second section contains limestone to insure the stability of water pH levels and charcoal as a biological treatment. Then the water flow to the third section which contain a biological filters and pumps after being treated in the first and second sections, where electric pump lift it again to the experimental aquariums through plastic tubes with a diameter of 0.5 in. Water from the two aquariums in the first row is drained to the two ones in the second row through holes installed in the middle of each aquarium. This hole is connected to a plastic tube whose height is less than water level and covered with a larger plastic tube to preserve feed. Each plastic aquarium has separate air pump for air supply and a cover fitted to prevent fish from jumping each contain several small ventellation holes.

Fish feeding experiments

Common carp *C. carpio* fingerlings, which were used in the experiment, were brought from the fish culture ponds of the Aquaculture Unit of the Agricultural Research Station at Al-Hartha, College of Agriculture, University of Basrah. Upon arrival to the laboratory, the stressed fish and those with divergent weights were excluded and the rest were placed in the aquariums and left to acclimatize for 3 days. Then the fish were weighed to the nearest 0.01 g using an electronic balance then the randomly distributed into the different aquariums (experimental units) with 10 fish per each.

Growth and Feeding Efficiency

Fish were acclimatized to RAS system before experiment initiation which lasted for 14 days. It was fed on a control diet at a rate of 3% body weight divided to two meals per day (9 am and 2 pm). The growth experiment started from January 6, 2021 to March 21, 2021. At the beginning of the experiment, 120 fish were individually weighed and the required number was assigned for each treatment separately. Then it was fed on the different assigned experimental diets at a rate of 3% of body weight. Fish was weighed biweekly to adjust provided diet quantity. Weight gain (WG), Relative growth rate (RGR), Specific growth rate (SGR) and Daily growth rate (DGR) for fish were calculated depending on the methods shown in Jobling (1993) according to the following equations:

Weight gain (gm) = final weight (gm) - starting weight (gm)

Relative growth rate (%) = weight gain (gm) / starting weight (gm) x 100

Specific growth rate (%) / (day) = natural logarithm of final weight (g) - natural logarithm of starting weight (gm) / period in days x 100

Feed conversion ratio = weight of feed served (gm) / weight gain of fish (gm)

Feed efficiency was calculated by calculating the feed conversion ratio and protein efficiency ratio based on Hepher (1988) according to the following equations:

Protein efficiency ratio (PER) = increase in body weight / protein intake

Value of protein produced (PPV) % = increase in body protein / protein intake x 100

Digestibility

The apparent digestibility of different experimental diets for common carp fingerlings was measured based on the indirect method described by Furukawa and Tsukahara (1966) using chromium oxide (Cr₂O₃) as a marker in the diets after adding 1% and reforming. The digestibility experiment was conducted after satiation and growth experiment for a period of 3 weeks. Fish were fed at 8 am on the diet containing the marker and left for an hour, then the unused feed was withdrawn with 70% water replaced and replaced with clean water, then fish was monitored for the time of excretion. Collected fish feces were mesh filtered, washed with distilled water in filter paper and left to dry at room temperature. Dried feces were collected after drying in airtight plastic bottles and kept in refrigeration. Chemical analyzes were carried out on dried feces samples to measuring the marker concentration by digesting the samples with concentrated nitric and perchloric acid (Olvera-Novoa *et al.*, 1994,) and photometric measurement at a wavelength of 350 nm. Nutrient digestibility coefficients were calculated using nutrient composition in diets and fish feces.

Chemical Analysis

The chemical composition of the diets was estimated based on the method mentioned in AOAC (2003). Moisture content was determined by oven drying at 105 °C for 24 hrs and until a constant sample weight is stabilized. For protein, Microkjeldahl method was used, and lipids were assessed by Soxhlet extraction with the organic solvent hexane. Ash content was determined after burning the samples in a muffle furnace at a temperature of 525 °C for 16 hours. Carbohydrate contents were estimated by difference according to the following equation:

$$\text{Carbohydrates \%} = 100 - (\text{moisture \%} + \text{protein \%} + \text{lipid \%} + \text{ash \%})$$

The total energy in the diets was calculated based on the method mentioned in New (1987), where the energy contents of nutrients, 4.1, 5.5 and 9.1 kilocalories / g of carbohydrates, protein and fat, respectively, were used.

Statistical analysis

The growth experiment was designed using a complete randomized design (CRD) with four treatments and three replicates for each. Revised Least significant difference (RLSD) was calculated to compare different means. All statistical tests were carried out using the Statistical package for social sciences (IBM SPSS) version 26.0.

Results and Discussion

Chemical composition of poultry waste protein concentrate (PWPC) and fish meal

Table (2) shows the chemical composition of poultry protein concentrate (including heads, legs, viscera) and fish meal used in this study. The moisture content of PWPC was 12.53%, protein 62.74%, fat 12.33% and ash 12.41%, while

the moisture content of fish meal was 8.66%, protein 53.82%, fat 8.31% and ash 29.18%, and the yield of PWPC was 20.35%. This result was consistent with that of EL-Husseiny *et al.* (2018) who used poultry by-product to feed the African catfish *Clarias gariepinus* where protein content in poultry by-product was 61.5%, fat 12.36% and moisture 5.16%. On the other hand, the protein content was 53.54% for the protein concentrate prepared from poultry wastes by Nandakumar (2013) which is lower than that recorded in the current study. Additionally, Mamoon *et al.* (2019) indicated when studying the nutritional properties and cost of poultry waste meal in diets of *C. gariepinus* fingerling that the chemical contents of the prepared concentrate were 47.1, 6.50, 13.31, 7.70% (protein, moisture, fat, ash) respectively, which again were lower than the results of the current study.

Taheri *et al.* (2013) recorded a protein content of 20.85% in the concentrate prepared by hydrolysis of poultry byproducts, which is less than the value of the protein in the current study. Moisture percentage in their study was 66.90%, fat 7.86% and ash 10.62%. In comparison with the current study, moisture was higher while fat and ash was lower. The quality of poultry waste products and its ingredients varies greatly depending on the raw materials and the manufacturing process (Watson, 2006) and the difference in quality could have significant influences on the growth and nutrient digestibility which require close quality control before applying in fish feeds (Shapawi *et al.*, 2007).

Table (2) Chemical composition of poultry waste protein concentrate (heads, legs, viscera) and fish meal

Composition	Content (%)	
	FM	PWPC
Moisture	8.66	12.53
Protein	53.82	62.74
Lipid	8.31	12.33
Ash	29.18	12.41

Amino acid profile of PWPC

Tables 3 show the values of essential and non-essential amino acid contents for PWPC and fish meal. It could be observed clearly that most of the essential and non-essential amino acids were available in the protein concentrate used in the current study for feeding common carp fingerlings, and it was comparative to those found contained in fish meal. The current results of the amino acid profiles are close to what was obtained by Aydin and Gumus (2013) in a study about the effect of poultry by product meal on growth performance and amino acid composition in young common carp. They that 50% of fish meal could be replaced by poultry waste meal in the diets of young tilapia (*Oreochromis niloticus*) without requirement to added amino acids

In comparison with the amino acid requirements of common carp based on NRC (2011), the protein concentrate in this study contained all required amino acids and met all the amino acid requirements of fish without a need to added amino

acids from other sources as shown in the studies of Abdel-Warith *et al* (2001) on African catfish *Clarias gariepinus*, Yang *et al.* (2004) on gibel carp *Carassius auratus gibelio*, Rawles *et al.* (2006) on Australian snapper *Morone chrysops* and Yildirim *et al.* (2009) on tilapia fish *Tilapia zilli*. It is noteworthy that differences in the availability of amino acids may depend mainly on the method of processing and technology used to extract the concentrate and the different quantities of components in the raw material such as bone, meat, skin and its derivatives (Shapawi *et al.*, 2007; Aydin and Gumus, 2013).

Table (3) Essential and non-Essential amino acids ($\mu\text{g}/100 \mu\text{g}$ protein) in PWPC and fish meal

	Essential amino acids										None essential amino acids							
	ARG	HIS	ISO	LEU	LYS	MET	PHE	THR	TRP	VAL	GLY	GLU	PRO	SER	SYS	ASP	TYR	ALA
FM*	4.11	2.07	3.12	4.01	4.78	1.45	2.28	2.78	0.76	2.89	5.48	6.91	2.94	3.13	0.92	5.48	2.29	3.53
PWPC*	4.78	2.08	3.01	5.34	3.8	1.16	2.95	1.54	0.33	2.07	6.46	7.62	3.72	2.12	1.48	4.82	1.84	4.05

FM*: Fish meal.

PWPC*: poultry waste protein consecrate.

Growth and Feeding Efficiency

Table (4) show the rates of initial weight (gm), final weight (gm), weight gain (gm), daily growth rate (gm/day), relative growth (%), specific growth rate (%/day), food conversion ratio (FCR), the percentage of efficiency of protein (PER%) and protein productive value (PPV%) of common carp fingerlings during the 72-day growth experiment. The results of the statistical analysis for the rates of weight gain, daily growth, specific growth and relative growth indicated significant differences ($P < 0.05$) between treatments (replacement and control), and the rates of weight gain, daily growth, specific growth and relative growth recorded the highest values in T3 diet (replacement ratio of 75%) reached 40.25 g, 0.62 g/day, 1.71%/day, 242.01%, respectively while the lowest values for it were recorded in the control diet C (0% replacement) 28.90 g, 0.44 g/day, 1.40 %/day, 173.29%, respectively. The results demonstrate that replacement process in T1, T2 and T3 diets gave better growth compared to the control diet where T3 diet had outperformed all other diets in the growth parameters. This could indicate the success replacement process in all the three diets although the T3 diet was distinctly the best. The results of the current study agree well with the results of the study of Siddik *et al.* (2019), who used biologically treated poultry by-products at 75% and 100% rates in the diets for Barramundi *Lates calcarifer*, noticing that the growth did not differ when replacing fishmeal with treated poultry waste meal. On the other hand, specific growth rate in the study of El-Husseiny *et al.*, (2018) ranges between 1.86-2.46 g/day using poultry waste meal in African catfish *Clarias gariepinus* diet while Ismail *et al.*, (2012) confirmed in their study on Malaysian mahseer *Tor tambroides* that replacing fish meal by 100% poultry waste meal did not affect survival, growth and body composition which is in line with the results of our study.

As shown by Yang *et al.* (2006), high-quality poultry waste products can replace fish meal in gibel carp fish *Carassius auratus gibelio* diets. However, they recommended an optimal fish meal replacement of only 65%, in contrast to Emre

et al. (2003) and Zabini (2011) who indicated increasing growth of Mirror carp (*Cyprinus carpio*) fingerlings with increasing poultry waste meal levels in the diet. Sabbagh *et al.* (2019) also showed that the complete replacement of fish meal by poultry waste meal in the diet of gilthead bream *Sparus aurata* can be achieved without compromising the growth performance and quality of fish suggesting that poultry waste meal can be considered as a good and sustainable raw material for fish feed manufacture. In any case, the discrepancy in the results of previous studies indicates that the quality of any protein component of the feed (fish meal or poultry waste) depends mainly on the quality of the raw material from which it was produced, as well as the type of material, processing and storage conditions, and the production method used to obtain the concentrate or dried meal.

It is noted that the fish fed on T3 diet (replacement ratio of 75%) recorded the highest feed conversion ratio of 1.31 compared to the control diet, which amounted to 1.60. Diets T1 and T3 scored 2.47% and 2.46%, respectively with significant differences between the treatments ($P < 0.05$). Productive protein value reached the highest level in T3 diet, which was 55.78% while the lowest was control diet C, which was 41.48% with no significant differences between treatments. Craig and Helfrich (2017) have shown that the feed conversion ratio (FCR) is one of the important criteria that indicate the feeding efficiency in fish, as it shows the relationship between the amounts of feed consumed and the weight gain while the protein efficiency ratio represents the relationship between the weight gain and the amount of protein intake. In addition, productive protein value represents the relationship between increase in body protein and the protein intake which used to assess the efficiency of benefiting from the ingested protein. In the current study, it was found that all of these parameters were good with the increase in the percentage of replacement to 75% of the fishmeal with PWPC. In contrast, a study by Dawsons *et al.* (2018) found that FCR and PER were significantly different from fish fed a diet containing 100% fishmeal. Srour *et al.* (2016) explained that replacing fish meal with poultry waste meal in seabass *Labrax dicentrarchus* diets was acceptable up to 60%, and that the 40% replacement is optimal in terms of maintaining fish survival rate at its best levels while the values of FCR, PER and PPV showed the best results when replacing 60% of the fish meal with poultry waste meal.

Table (4): Growth and feeding efficiency related parameters of young common carp *C. carpio* fed on experimental diets

Parameters	Treatments			
	Control	T ₁	T ₂	T ₃
Initial weight (g)	16.68± 0.24 ^a	16.71±0.52 ^a	16.66±0.51 ^a	16.65±0.32 ^a
Final weight (g)	45.58±1.03 ^c	53.37± 4.7 ^{ab}	48.94± 1.76 ^{bc}	56.90± 2.71 ^a
Weight gain WG (g)	28.90±0.80 ^c	36.66± 5.04 ^{ab}	32.28± 1.37 ^{bc}	40.25± 3.03 ^a
Relative Growth Rate RGR (%)	173.29± 2.4 ^c	219.93± 5.4 ^{ab}	193.76± 6.2 ^{bc}	242.01± 22.4 ^a
Specific growth rate SGR (% g-day)	1.40± 0.01 ^c	1.61± 0.16 ^{ab}	1.50± 0.03 ^{bc}	1.71± 0.09 ^a

Feed conversion rate FCR	1.60 ± 0.03 ^b	1.31 ± 0.18 ^a	1.48 ± 0.05 _{ab}	1.31 ± 0.09 ^a
Protein efficiency ratio PER	2.07 ± 0.03 ^b	2.47 ± 0.33 ^a	2.18 ± 0.07 ^{ab}	2.46 ± 0.17 ^a
Productive protein value PPV (%)	41.48 ± 9.7 ^a	45.51 ± 7.3 ^a	46.34 ± 8.90 ^a	55.78 ± 2.42 ^a

n = 3 (three samples from each treatment); mean ± SD; mean values within the same row with different superscript letters are significantly different (P<0.05).

Digestibility

The results in Table (5) indicate the values of the total apparent digestibility and the apparent digestibility of nutrients in experimental diets, showing the effect of replacing poultry waste protein concentrate in the diets for common carp fingerlings. It could be noted that highest total digestibility coefficient, which reached 91.03%, was for control diet C (0% replacement ratio) and the lowest was 86.45% for T2 diet (50% replacement), while the digestibility values for T1 ration (25% replacement) and the T3 diet (replacement ratio of 75%) was 86.83% and 88.81%, respectively, with no significant differences between the treatments. The control treatment excelled in the digestibility of nutrients (protein, fat, and carbohydrates) followed by T3, T1 and T2, respectively, with no significant differences also between treatments. In contrast, Hernandez *et al.* (2014) found digestibility of nutrients in spotted rose snapper *Lutjanus guttatus* diets were lower as the proportion of fish meal was replaced with poultry waste meal, with significant differences between treatments and they attributed this decrease in digestibility to the lack of amino acids present in the diets with increased replacement rates especially the lack of lysine and methionine. Moreover, Zhou *et al.* (2004) obtained higher values for apparent digestibility coefficient (ADC) of about 90.5% with poultry by-products meal. On the other hand, Dawson *et al.* (2018) found that protein and fat digestion were good with all replacement rates and ranged for protein from 82-84% and for fat between 90-92%. Raw materials used to prepare protein concentrates with a high content of skeletal elements like bones and ash recorded lower protein digestibility coefficient (Sugiura *et al.*, 2000; Najim *et al.*, 2014). The apparent digestibility coefficient of protein in the current study was relatively high, especially for T3 treatment, and this indicates that the protein concentrate used was of high quality and low in ash, suitably digestible and close to fish meal composition which facilitate fish digestive system to deal with it as an acceptable feed ingredient. The results of the current study are consistent with Takakuwai *et al.* (2006) who used poultry waste meal by 40% with or without the added amino acids. At the same time, Yones and Metwali (2015) showed that protein digestibility increases directly with substitution rate and ranged between 94.3-94.6%. The apparent digestibility coefficient of fat was also high for all treatments and compared to the control diet, which indicates that it was digestible as that found in fish meal. Shapawi *et al.* (2007) tested hump back grouper *Cromilepte altivelis* diets with 75% and 100% replacement of fish meal with poultry waste meal and found that fat digestibility did not differ from that of control diet. Apparent digestibility coefficient of carbohydrates was also high in the current study which agree well with Soltan (2009) who showed that adding feed materials such as corn and wheat as a source of carbohydrates with replacing fish meal by poultry by product meal in the diets for Nile tilapia *O. niloticus* did not adversely affect digestibility of carbohydrates.

Table (5) Total apparent digestibility coefficient and the apparent digestibility coefficient of nutrients % in the experimental diets of common carp *C. carpio* fingerlings

Composition	apparent digestion coefficient (%)				
	Diet	control	T1	T2	T3
Total					
Digestion		91.03 ± 2.21	86.83 ± 2.59	86.45 ± 1.32	88.81 ± 0.80
Coefficient					
Protein		94.28 ± 1.42	92.31 ± 1.46	92.08 ± 0.67	93.27 ± 0.52
Lipid		95.32 ± 0.14	93.06 ± 1.40	92.80 ± 0.68	95.20 ± 0.23
carbohydrate		93.15 ± 1.70	90.09 ± 1.90	89.52 ± 1.00	91.49 ± 0.64
Ash		73.18 ± 5.77	57.78 ± 9.42	57.78 ± 9.42	64.82 ± 2.08

n =2 The values are mean ± standard deviation.

Conclusions

It could be concluded from the current study that it is possible to enhance environmental health and obtain resource sustainability by preparing a protein concentrate from recycled poultry wastes. This recycled concentrate is characterized by good nutritional properties which make it suitable and efficient to use as a partial alternative for fish meal at replacement rates up to 75% of fish meal content in diets intended for common carp fingerlings, without any adverse effects on growth and feeding efficiency of the cultured fish as well as digestibility of whole diet or its different component nutrients.

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