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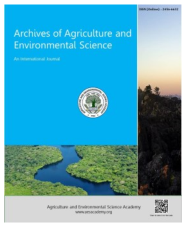

ORIGINAL RESEARCH ARTICLE

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Assessing fat and aquaculture feed recyclable from chicken wastes of poultry slaughterhouse in Bojnoord, North Khorasan Province, Iran

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ABSTRACT

The rapid growth of poultry industry has caused large amounts of chicken wastes that must be recycled regarding environmental and economic concerns. This study aimed to assess the fat and aquaculture feed producible from chicken wastes in the Bojnoord poultry slaughterhouse, Iran. The chicken wastes including fatty tissue, viscera, and coccygeal were sampled at three different periods in 2016. Fat samples were analyzed by gas chromatography for determining the fatty acid (FA) profile. The degreased wastes then were used for producing aquaculture feed pellets once in combination with flour and once in mix with poultry by-product meal (PBM). The pellets were tested for physicochemical properties. Averagely, 58.9% of the fatty tissue, 14.5% of the viscera, and 30.4% of the coccygeal were recycled as fat content. Totally, 109368 kg-fat/year was extractable from chicken wastes. The oleic, palmitic, stearic, and palmitoleic represented more than 80% of the total FA content. 67.41% and 67.16% of FA composition was unsaturated and composed of cis-isomers, respectively. The iodine value (IV) and saponification value (SV) were 58.7 g iodine/100 g oil and 156.12 mg KOH/g oil, respectively. The content of moisture, protein, fat, fiber, and ash in the feed composed of degreased chicken wastes and PBM was 7.8, 41.2, 34, 0.9, and 4.4 %, respectively. The fat obtained from chicken wastes was suitable for non-edible consumption. Combining degreased wastes with PBM resulted in protein-rich aquaculture feed. This study showed the economic and health benefits of separating components of the poultry slaughterhouse wastes and the possibility of producing aquaculture feed containing suitable micronutrients from these wastes.

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INTRODUCTION

In recent decades, poultry products have played a great role in the supply of meat and protein requirements of different communities (Roshani *et al.,* 2012). The commercial poultry production has experienced an impressive expanding mainly because of the rapid turnover rate, the short incubation period (i.e. 21 days) (Akanni and Benson, 2014), the reduced production costs and the enhanced incomes of people (Axtell, 1999). The share of poultry sector in the production of meat in the worldwide scale has been increased from 15% in the past three decades to 30% in current years. The rate of growth in the poultry industry has been shown as a greater value in comparison to the industry of bovine meat production (Gerber *et al.,* 2007). It is expected that poultry industry continues to its development in the foreseeable future (Axtell, 1999). Many industries can be established following the expansion of poultry farming such as hatchery, broiler breeder or parent stock farms, feed mills, factories producing equipment and processing plants (Raha, 2007). On average, 33% of the slaughter weight of a chicken converts to by-products (Woodgate and Van der Veen, 2014). The wastes resulted from poultry processing steps can be recycled for raw materials or can be converted to new products of higher value. This exploitation is important from economic and environmental aspects. Non-utilization of these wastes results in loss of a valuable source of potential revenue and imposes the cost of disposing (Jayathilakan *et al.,* 2012; Kumar *et al.,* 2017). Hence, by-products can be seen as a challenge regarding the increased pressure for reduction of these wastes and also as an opportunity for the profitability of the meat industry (Barbut, 2015). Currently, the number of industrial slaughterhouses of poultry in Iran is 67 (Sayed-Hassani *et al.,* 2014). The type and amount of wastes produced in the poultry industrial units in Iran is diverse, enormous and inconsistent with international standards. According to estimates, the animal losses in Iran poultry units are about 3 times greater than the global standards which cause huge economic losses (Shahvali and Rahimi, 2006). Improper handling and ignorance of poultry by-products can create environmental pollution, and aesthetic problems. They are also a potential hazard for human health (Jayathilakan *et al.,* 2012) as the fresh and decomposing waste products in the poultry facilities produce odor and attract flies and many of the other pests. Poultry buildings and manure storage facilities are main sources of odor emission, and ammonia, volatile organic compounds, and hydrogen sulfide are major contributing substances in producing odor. The amount of odor emission is controlled by several factors including the frequency of chicken-house cleaning, the status of temperature and humidity of the manure, the way of manure storage, and the condition of air exchange. The flies and mosquitos cause nuisances for residents who live near these facilities and can also act as a vector for disease transmission. Cholera, dysentery, typhoid, malaria, filaria and dengue fever are some of diseases transmittable by insects. But local disturbances resulted from odor, flies, and rodents are not the only concern. Damage to the landscape in the surrounding of the poultry farm, and pollution of natural resources including soil and water with nutrients, pathogens and heavy metals caused by poor condition of management and storing of manure are the other concerns. Furthermore, pesticides which are used for controlling disease vectors cause pollution in ground- and surface waters (Gerber *et al.,* 2007). A variety of pollutants at high and variable concentrations have been detected in wastewater of the meat industry. Use of water for scalding, removal of feathers, washing birds, chilling, equipment cleaning, and mechanical equipment cooling naturally generate wastewater in poultry processing plants. According to a number of studies, the mean value of wastewater generated in chicken processing plants was 9.3 gallon per bird (Jayathilakan *et al.,* 2012). Beside to the soil and water, air is also affected by the poultry production. Among different producers of meat, the poultry slaughtering industry is a more energy-intensive sector (Ramirez *et al.,* 2006), and use of fossil fuels for energy supply in the poultry processing facilities causes carbon dioxide emissions (Gerber *et al.,* 2007).

With respect to this fact that usually urban or peri-urban areas are considered for constructing slaughterhouse, the lack of enough land for establishing facilities required for waste management can increase the risk of environmental effects (Gerber *et al.,* 2007). Waste management in slaughterhouses mainly refers to the way that manure, litter, and dead birds are handled. Depending on the depth of caged-layer houses, the manure could be accumulated from several months to several years. The common way of manure disposal is flushing into lagoon which must be designed and managed properly to prevent the breed of mosquitos. Litter is a mixture of feces, spilled feed, and feathers and must be dried by providing proper air flow, drainage, and removal of water leaks. Although the frequency of chicken-growth houses cleaning is often influenced by economic considerations, it should be noticed that the longer stay of litter in them encourages the beetle production. As the bird mortality is an inevitable part of poultry production, always there would be a number of carcasses requiring disposal. Considering dead birds promote insect development, they should be removed daily (Axtell, 1999).

The types of poultry by-products have been determined in the poultry meat processing book. Accordingly, feathers, heads, blood, gizzard and stomach, feet, and finally the intestines and glands constitute respectively 7-8, 2.5-3, 3.2-3.7, 3.5-4.2, 3.5-4, and 8.5-9% of the weight of a chicken (Sams, 2001). The poultry by-products which are not utilizable for human consumption can be converted into products marketable for agricultural or industrial usages (Woodgate and Van der Veen, 2014). The dead animals, the scraps connected to the meat including blood, fatty tissue, and bone, the viscera, and the feathers can be used correctly in this way (Jayathilakan *et al.,* 2012). There are some specialized industrial units for processing blood in the world that produce blood plasma, hemoglobin, and blood meal (Woodgate and Van der Veen, 2014). For every 5 kg of fresh chicken blood, 1 kilogram of blood powder with a moisture content of 10-12% would be achieved which is rich in lysine and thus can be used as a rich protein chicken meal (Nabizadeh, 2011). 90% of the feathers structure is composed of protein, so they are a rich source for animal feed. The use of feathers can create an important source of revenue as they can be applied in the manufacture of bedding, ornaments, and sporting equipment. Furthermore, they have found a wide usage as filler of fertilizer (Ockerman and Hansen, 1999). Gelatin is another product which can be obtained from the poultry skin and bones (Karim and Bhat, 2009). It has usages as plasma expander for blood, as an excellent emulsifier for many of the emulsions and also in printing industry (Jayathilakan *et al.,* 2012). New investigations show the high potential of gelatin obtained from poultry for being replaced with gelatin extracted from mammalian (Sarbon *et al.,* 2013).

Worldwide, annually 25 million tons of animal fats and oils are produced. In Europe, about 2.8 million tons/year of animal fats are processed from slaughter byproducts. The natural basis, versatility and sustainability of these fats, have caused their applications for many of food and non-food consumptions (Woodgate and Van der Veen, 2014). From last decades, the animal fats have been used for the production of waterproof clothing, soap and candle (Barbut, 2015), while nowadays a diverse number of oleo-chemical products are made out from animal fats and oils. The most recent application of animal fats was seen in the production of renewable bio-functional building blocks for the manufacture of plastics or biopolymers (Woodgate and Van der Veen, 2014). The animal fats have been also applied for the low-cost production of biodiesel or biofuel (Zhang *et al.,* 2003). The chemical structure of animal fats is composed of glycerol and fatty acids (FA). Determining the FA profile in fats extracted from different species has importance especially for certain applications. For example, in feed applications, particularly for the production of high-quality feed pellets, determining the FA composition as an important feature seems essential (Woodgate and Van der Veen, 2014). The aim of this study was evaluating the quantity and quality of fat and aquaculture feed recyclable from chicken wastes produced in the Parandis poultry slaughterhouse, Bojnoord, North Khorasan Province, Iran.

MATERIALS AND METHODS

The slaughterhouse characteristics and sampling: The Parandis poultry slaughterhouse is located 2 kilometers away from the east of Bojnoord city. It slaughters chickens produced in the North Khorasan province and other neighboring provinces. The slaughterhouse has been constructed on an area of 2 ha and consists of a slaughter salon, a chicken refrigeration unit, a packaging salon, a waste conversion unit and a waste water treatment facility. The produced wastes in mixture with wastewater are transferred to the separator, where wastewater would be moved to the treatment unit and wastes are separated. The mixed by-products which include chicken heads, feet, feathers, internal organs etc. are transmitted into the cooking double glazed pot and then would be converted to poultry meal of few economic values after 10 to 12 hours. To obtain an average value of the fat content in each of the chicken wastes including fatty tissue, viscera tissue, and coccygeal tissue, sampling was conducted in three different time intervals in early spring of 2016 that was equal with the beginning of 1395 solar year based on the Iranian calendar. The weight of the wastes taken from each of the fat-containing tissues at each period of sampling was 1 kg. Thus, considering 3 periods of sampling and 3 sampled tissues at each sampling period, a total of 9 kg of chicken wastes were collected and examined for fat content.

Extraction and characterization of fat content: To extract the fat content from chicken wastes, water was added to the wastes and the mixture was heated at water boiling point. Considering the low resistance of animal cell membrane, heating which increases the fat volume, causes the membrane rupture and as a result exiting the fat. On the other hand, given that the density of fat is less than water, the fat floats on the water surface. Heating the chicken wastes at boiling point not only cause fat extraction, but also can lead to the destruction of pathogens which has importance as the wastes would be converted to aquaculture feed. To facilitate the exit of fat from chicken tissues, a manual meat grinder was used to comminute samples before fat extraction. At each period of sampling, a determined amount of comminuted chicken wastes including fatty tissue, viscera and coccygeal (1 kg from each tissue) were poured separately into 2 L beakers. Then a little water was added to each beaker and a grid was installed on the top of that to prevent from the floating of the wastes on the beaker surface. When the temperature reached to 95 ° C, the fat content was exited from the tissue and floated on the liquid surface. The liquid content of the mixture was transferred into a separating funnel, where the fat and water were separated based on the density difference. Then, to complete the extraction of fat content, the mixture of water and wastes were heated again for several times at boiling point.

To identify the characteristics of the extracted oil, three experiments were conducted. Accordingly, the IV, SV and FA composition of the fat content were determined. IV and SV were measured according to the standards set by the Iranian National Standardization Organization (INSO) with standard No. 4888, and standard No. 10501, respectively in the food and drug laboratory of North Khorasan province. The FA composition was determined according to the standard No. 4091 in the food quality control laboratory of Testa, Razavi Khorasan province. The Agilent 7890A gas chromatograph with flame ionization detector (FID) was applied for the analysis of FA profile. The Wax-type fused silica column was 30 m in length with an internal diameter of 0.25µ. The initial temperature of the injector was 235 °C and detector temperature was kept at 250 °C. Nitrogen gas and hydrogen-air mixture were used as the carrier gas and the fuel of the detector, respectively. The time of detection was 40 min.

Aquaculture feed production: To prepare aquaculture food pellets, the mixture of the degreased chicken wastes including fatty tissue, viscera and coccygeal, once were combined with flour and once with the PBM that was produced using the chicken wastes in poultry site. The mixing ratio was 1:1 in both cases. Then, the pasty mass obtained from each of the combinations was minced and placed in a warm location to be dried. Finally, the produced pellets were sent to the Mizan laboratory in Bojnoord city to be investigated in terms of the main items that must be measured in the aquaculture feed. Accordingly, the percent of moisture, total ash, total protein, crude fat, and raw fiber in the produced pellets were determined through the INSO instructions of the standard No. 321, 332, 457, 415, and 520, respectively. Figure 1 represents a schematic diagram in which all the chicken wastes processing operations are simplified.

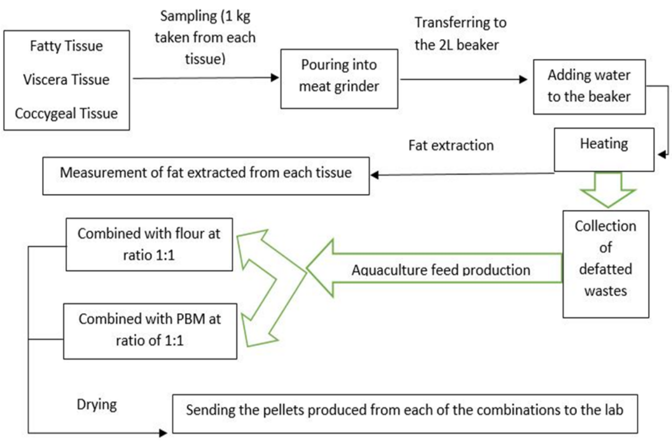

Figure 1. *Overview of poultry waste processing operations.*

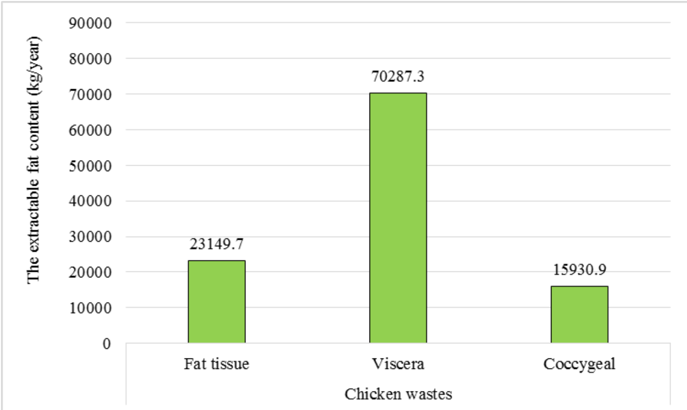

Figure 2. *The total estimated values of poultry fat extractable from fatty, viscera and coccygeal wastes in Bojnoord slaughterhouse from mid-march of 2015 to mid-March of 2016.*

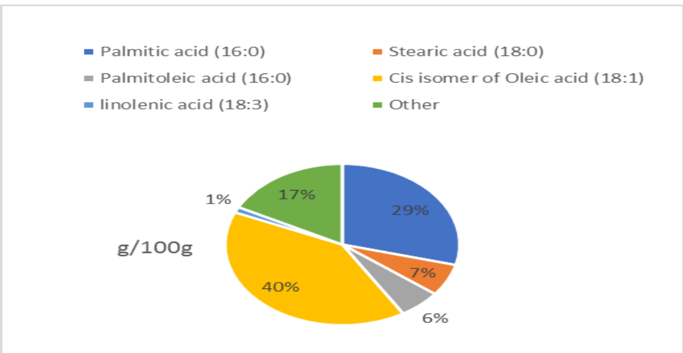

Figure 3. *Fatty acids (FA) composition of the fat extracted from chicken wastes.*

Figure 4. *Aquaculture feed pellets obtained from defatted chicken wastes.*

RESULTS AND DISCUSSION

The amount of extractable fat: Table 1 provides the average value of fat content extracted from each of the chicken wastes. Obviously, the most content of fat, were recovered from wastes of fatty tissue. The recovered fat content from 1 kg of each of the coccygeal, and viscera wastes were 30.4%, and 14.5%, respectively. Although it must be noted that the amount of chicken tissues in the form of fat (3%) and coccygeal (4%) is very low in comparison to the viscera wastes (37%). According to the statistics provided by veterinary network of Bojnoord city, the total weight of fatty, viscera, and coccygeal wastes were 39303.4, 484742.3, and 52404.5 kg per year (mid-march 2015 to mid-march 2016), respectively. So according to the amount of extractable fat content from each of the tissues (Table 1), the average annual amount of recoverable fat from poultry slaughterhouse wastes is calculated and shown in Figure 2. Totally, 109368 kg/year of fat content was extractable from chicken wastes including fatty tissue, viscera, and coccygeal. Taking into account that the sale price of 1 kg of fat is 11000 Rials in Iran currency, the profit that would be obtained from the sale of total fat content (109368 kg) which is extractable from chicken wastes in one year in the Bojnoord poultry slaughterhouse, is 1203048000 Rials or US $ 31,500.

Fatty acids (FA) composition, IV and SV: Table 2 summarizes the results of the chicken wastes FA profile which are expressed as g of a given FA on 100 g of chicken fat extracted from Bojnoord poultry slaughterhouse wastes. The sum of the numbers given in the Table 2 did not reach 100 because some of the FAs were not detectable in the gas chromatography (GC) analysis.

Table 2 reflects the unsaturated nature of FA profile in the fat content obtained from the chicken wastes as the proportion of unsaturated FA was 67.41 g/100g while the saturated FA ratio was 32.51 g/100g. Figure 3 represents FA composition determined for the fat extracted from chicken wastes. Among FA, oleic, palmitic, stearic, and palmitoleic represented more than 80% of the total FA content. The most abundant FA was cis isomer of oleic acid. The cis FA was 67.16 % while the Trans FA were 0.25 %. The IV of the oil extracted from chicken wastes was determined at 58.7 g iodine/ 100 g oil. The SV of the studied oil was 156.12 mg KOH/ g oil.

The IV is an index of unsaturated fats and oils (Akbar *et al.,* 2009). In other words, the IV has a direct relationship with the number of double bonds (Gopinath *et al.,* 2008). The results of current study showed that in the FA composition corresponding to the fat content obtained from chicken wastes, the amount of unsaturated FA was remarkably higher than saturated. This was caused by high content of oleic acid, a very suitable precursor for making biopolymers (Woodgate and Van der Veen, 2014). The higher proportion of unsaturated FA in fats and oils causes their better digestibility (Doppenberg and Van der Aar, 2010). Although, the unsaturated FA is oxidatively unstable (Adewale *et al.,* 2014) and thus has been known less suitable for frying and baking applications (Woodgate and Van der Veen, 2014). From another perspective, unsaturated FA and cis isomers of them reduce the unhealthy cholesterol (LDL) (Mensink *et al.,* 2003). According to the results of present research, the amount of cis-FA in the fat obtained from the chicken wastes was 269 times greater than trans-FA. SV describes the average molecular weight of FA and its higher value indicates the longer-chain of FA. Considering table 2, oleic, palmitic, and stearic were long-chain FA dominant in the studied fat content. With respect to the literature review, the IV and SV measured in the fat content obtained from chicken wastes were not as much as the amount of these indices in the edible fats and oils (Endo *et al.,* 2005). Hence, the obtained fat cannot be recommended for human consumptions. But according to Farmani and Rostammiri (2015) edible fat was also extractable from chicken skin wastes. Based on the experiments conducted by them, palmitic acid was the main saturated FA in the composition of the chicken waste fat, while the oleic and linoleic acids were principal unsaturated FAs. They expressed that FA obtained from chicken waste fat had a composition similar to the rice bran oil and its saturated FAs were significantly lower than beef tallow, lard and palm oil. In a comparison carried out by Woodgate and Van der Veen (2014) between FA profiles of animal and vegetable fats, it was shown that the content of saturated FAs in the chicken fat was lower than some vegetable oils including coconut and palm oils, and also it was less than animal fats such as beef tallow and pork lard.

Aquaculture feed: The aquaculture feed obtained from defatted chicken wastes is shown in figure 4. The physicochemical properties of two types of the aquaculture feed produced in current study are expressed in Table 3. The measured indexes are also compared with the feed produced by the Faradaneh Company, a well-known aquaculture animals' food producer in Iran. As Table 3 indicates, the protein value, and the fat content in the aquaculture feed obtained from the combination of chicken wastes with PBM were much higher than their levels in the feed produced from combination of chicken wastes with flour.

According to environmentally and financially considerations, fish meal is not a sustainable source of feeds, so it must be replaced with more environmental friendly and cost-effective feeds (Tabinda and Butt, 2012). Assessing the nutrient composition and digestibility is the essential step to consider PBM as a potential feed ingredient (Rawles *et al.,* 2016). Feed-grade poultry by-products which have been replaced a proportion of the fish meal are produced from processing waste streams without paying enough attention to the final product. Consequently, the nutritional quality of the produced meal may be significantly different dependent on the time of production or source of the product (Sealey *et al.,* 2011). To determine the suitability of the produced feeds to meet the nutritional demands of the fish, they were assessed in terms of the level of energy producing substances such as protein and lipid. In addition, they should contain water and substances such as minerals and fiber to satisfy the other needs of fish (Meilisza *et al.,* 2011). According to the results presented in Table 3, the feed pellets produced from the combination of degreased chicken wastes and PBM had more values of moisture and protein in comparison to the flour-containing pellets. Among the fish need nutrients, proteins are considered as the most important and most expensive part of the diet (Marammazi *et al.,* 2013). Hence, the manufacturers of aquaculture diet produce feed at the lowest level of protein that successfully supply the essential amino acids required for fish without compromising its performance (Rawles *et al.,* 2017). According to the results of literature review, chicken intestine is a rich source of protein (Tabinda and Butt, 2012). Wet feeds are more digestible and due to the supply of amino acids and vitamins, increase the feed efficiency and growth of fish (Marammazi *et al.,* 2013). The digestibility also depends on the proportion of unsaturated acids. The most digestibilities of fatty acids have been attributed to the myristic acid, followed by linoleic, oleic, palmitinic, palmitic, and stearic acids (Woodgate and Van der Veen, 2014). Hence, with respect to the findings, the fat extracted from chicken wastes in current research which showed a high proportion of oleic and palmitic acids were acceptable in terms of a digestibility. The fat content of the protein-rich feed was much higher than the needed values and was not comparable with the fat content of the commercial grade aquaculture feed provided by Table 3. Presence of fat in the diet would be beneficial until the fish can use it as an energy source for growth. Furthermore, high intake of fat by fish causes storage of fat in its carcasses and has adverse effects on its growth(Marammazi *et al.,* 2013). Some researchers have studied the use of PBM for aquaculture feeding. In the study conducted by Sayed Hassani *et al.* (2014) the values of moisture, protein, fat, fiber, and ash in the PBM that was evaluated as an alternative protein source for Huso Huso within growth period were 7.3%, 64.25%, 1.5%, 2.1%, and 8.1%, respectively. The results of the study carried out by Nafisi-Bahabadi *et al.* (2002) who reported that PBM can be substituted with fish meal without any need to be enriched with amino acids and with no negative impact on the growth of salmon. This replacement is also important from an economic perspective considering the higher price of fish meal in comparison to the PBM. Kalantar and Fahimi (2005) investigated the qualitative characteristics in the samples of PBM to study the effect of using that in broiler feeding. According to the results conducted on samples, the average amounts of crude protein, fat, calcium, and phosphorus were 53%, 14.58%, 0.963%, and 0.776%, respectively. They believed that the product can be applied as broiler meal. Ridwanudin and Sheen (2014) evaluated the dietary fish silage combined with PBM for being replaced with fish meal. The highest growth performance of *Epinephelus coioides* was achieved when the fish fed diet was combined with 20% PBM. The amounts of ingredients including moisture, crude protein, crude lipid, crude fiber, and ash in the composition of dietary fish combined with PBM were 3.86%, 45.98%, 12.10%, 12.39%, and 9.75%, respectively. Based on the investigation performed by Farmani and Rostammiri (2015), the content of fat, moisture, protein and ash in the chicken wastes was equal to 38.92%, 50.78%, 8.93%, and 1.28 %, respectively.

Table1. The average fat content extracted from chicken wastes of Bojnoord poultry slaughterhouse.

Chicken tissue	Sampling period	The amount of extracted fat in kg	The amount of extracted fat in percent	Average in percent
	1	0.325	32.5	
Fatty	2	0.758	75.8	58.9
	3	0.686	68.6	
	1	0.145	14.5	
Viscera	2	0.135	13.5	14.5
	3	0.155	15.5	
	1	0.445	44.5	
Coccygeal	2	0.189	18.9	30.4
	3	0.279	27.9	

Table 2. Fatty acids (FA) composition of chicken wastes determined by GC.

Fatty acid (FA)	g/100 g
Lauric acid (12:0) [a]	0.08
Myristic acid (14:0)	0.059
Pentadecanoic acid (15:0)	0.08
Palmitic acid (16:0)	29.09
Margaric acid (17:0)	0.09
Stearic acid (18:0)	6.42
Arachidic acid (20:0)	0.16
Myristoleic acid (14:1)	0.14
Palmitoleic acid (16:1)	5.83
Heptadecenoic *acid* (17:1)	0.06
Trans isomer of Oleic acid (18:1)	0.21
Cis isomer of Oleic acid (18:1)	40.21
Trans isomer of Linoleic acid (18:2)	0.04
linolenic acid (18:3)	1.13

[a]. Carbon number: number of double bonds

Table 3. The physicochemical properties of the produced aquaculture foods in comparison to commercial aquaculture feed.

Aquaculture feed	Physicochemical properties				
	Moisture (%)	Protein (%)	Fat (%)	Fiber (%)	Ash (%)
The product obtained from the combination of degreased wastes and flour	6.7	14.5	9	5.5	3.4
The product obtained from the combination of degreased wastes and PBM	7.8	41.2	34	0.9	4.4
The product of Faradaneh company	5-11	38-54	11-15	1.5-4	7-13

Conclusions

In this research, the feasibility of recycling and reuse of chicken wastes of the poultry slaughterhouse in the form of fat and aquaculture feed was studied. It was shown that 58.9% of the fatty tissue, 14.5% of the viscera, and 30.4% of the coccygeal were recyclable as fat content. 67.41% and 67.16% of FA composition was unsaturated and composed of cis-isomers, respectively. According to the expressed results for FA composition, and with respect to the levels of IV, and SV, that were obtained equal to 58.7 g iodine/100 g oil and 156.12 mg KOH/g oil, respectively, the fat extracted from chicken wastes was not suitable for edible consumptions. The content of moisture, protein, fat, fiber, and ash in the feed composed of degreased chicken wastes and PBM was 7.8, 41.2, 34, 0.9, and 4.4 %, respectively, which shows that this mixture can be satisfactory applied as a rich-protein source of aquaculture feed.

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Competing interests: There is no conflict of interest to be reported by the authors.

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