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Assessment of Chemical Composition and Mineral Contents of Iranian Kilka Fish Meal

Hossein Jahanian Najafabadi*
[a] Department of Animal Sciences, Faculty of Agriculture, Bu-Ali Sina University, Hamedan, Iran.

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Abstract

This experiment was performed to investigate the chemical composition and mineral contents of Iranian Kilka fish meal (KFM). A total of 6 composed samples of KFM were prepared during one month sampling period from rendering units of two commercial fish meal plants in Gilan province. The results of proximate analysis indicated that the average dry matter (DM), ether extract (EE), crude protein (CP), crude fiber (CF) and ash contents of the KFM samples were 94.76, 23.11, 59.72, 0.67, and 13.05 percent, respectively. The average gross energy (GE) value for the KFM samples was 5592 kcal kg^{-1}. The average values of major elements including Ca, P, Na, K, Cl, Mg, and S were 3.92, 2.58, 0.87, 0.56, 0.69, 0.29, and 0.43 percent, in order. The average values for trace elements including Fe, Cu, Mn, Zn, and Se were 223.8, 5.9, 3.9, 79.6, and 1.64 mg kg^{-1}, respectively. There were significant negative correlation coefficients ($P<0.05$) between ash and EE, CP and GE contents of the KFM samples so that the EE, CP and GE values of the KFM samples decreased as ash content increased. Therefore, it seems that the ash content is a good indicator for prediction of other chemical composition and GE content of KFM.

1. Introduction

Fish meal can be produced from whole fish or wastes from the use of fish prepared for human consumption (Ponce and Gernat, 2002; Ween *et al.*, 2017; Adibrata *et al.*, 2022), but currently fish meal is mostly produced from smaller oily fish caught specifically for fish meal production (Leeson and Summers, 2001, 2005). High quality fish meal has excellent amino acid balance (Ponce and Gernat, 2002; Khatoon *et al.*, 2006) and is rich in protein and amino acids (specially methionine, lysine, arginine and tryptophan), calcium, phosphorus, iron, vitamin B_{12}, choline, niacin, pantothenic acid and riboflavin (Miller, 1970; Waldroup and Adams, 1994; NRC, 1994; Ponce and Gernat, 2002). In addition, fish meal is a good source of energy (Ponce and Gernat, 2002) and omega-3 fatty acids (Hulan *et al.*, 1989; Burke *et al.*, 1997) specially Eicosapentaenoic acid and Docosahexaenoic acid (Shahmohammadpour Askari *et al.*, 2025). Fish meal is used as a source of protein and unidentified growth factors in diets of monogastric animals like pig (Kim and Easter, 2001), Poultry (Sibbald and Wolynetz, 1984; Wu *et al.*, 1984; Ponce and Gernat, 2002; Khatoon *et al.*, 2006), Pet Animals (Folador *et al.*, 2006; Ween *et al.*, 2017) and aquatic animals (Anderson *et al.*, 1993; Steffens, 1994; Ahmad and Ibrahim, 2016; Rahim *et al.*, 2017; Zamani *et al.*, 2017; Rathika and Pugazhendy, 2018; Hodar, 2020; Al-Noor *et al.*, 2023; Majluf *et al.*, 2024; Shahmohammadpour Askari *et al.*, 2025) and also extensively used as a ruminally undegradable protein source in ruminant diets (Petit and Flipot, 1992; Petit and Castonguay, 1994; Streeter and Mathis, 1995; Burke *et al.*, 1997; Walz *et al.*, 1998). The chemical composi-

*Corresponding author: H. Jahanian Najafabadi (Assistant Professor)
E-mail address: jahanian@basu.ac.ir
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tion and mineral contents of fish meal can vary greatly depending on the species of fish used (Wu *et al.*, 1984; Ponce and Gernat, 2002; Khan *et al.*, 2012), amount of residual oil (Anderson *et al.*, 1993), processing method (Bayrakli and Duyar, 2021), drying method and temperature (Anderson *et al.*, 1993; Rosselot *et al.*, 1996), and whether the meal is made from whole fish or the waste from some other processing operation (Anderson *et al.*, 1993), thus the chemical composition and mineral contents of fish meal is highly variable (Khan *et al.*, 2012) and needs to be evaluated continuously.

Determination of chemical composition of fish meal is important in estimating its metabolizable energy content (Sibbald and Wolynetz, 1984; NRC, 1994) and measurement of its mineral content especially calcium and phosphorus is of significance to include fish meal in the balanced diets (NRC, 1994; Leeson and Summers, 2001, 2005).

Kilka fish belongs to kingdom of *Animalia*, phylum of *Chordata*, class of *Actinopterygii*, subclass of *Teleostei*, order of *Clupeiformes*, family of *Clupeidae*, subfamily of *Ehiravinae*, genus of *Clupeonella* and species of *Engrauliformis* in animal systematic classification system (Abtahi *et al.*, 2004; Keramat Amir Kalayi and Karimzadeh, 2013). In Iran, Kilka fish with the scientific name of *Clupeonella engrauliformis* is obtained from the Caspian Sea in Golestan, Mazandaran and Gilan provinces. The most part of the catch is processed into fish meal by different processing methods. Now, there are 9 rendering plants in Iran that produce Kilka fish meal by processing whole Kilka fish, which is mostly used in poultry and cold water fish diets. Although several studies have been conducted on chemical composition and mineral contents of fish meal in other countries (Schumaier and McGinnis, 1969; Miller, 1970; Sibbald and Wolynetz, 1984; Anderson *et al.*, 1993; Ponce and Gernat, 2002), but the chemical composition and mineral contents of Kilka fish meal produced in Iran has not been described quantitatively. Therefore, the current study was conducted to determine the chemical composition and mineral contents of Iranian Kilka fish meal.

2. Materials and Methods

The Kilka fish meal (KFM) samples were provided during one month sampling period from rendering units of two industrial fish meal plants in Gilan province. Each sample was randomly taken from different parts of a batch. The samples collected in each five days were mixed together and 6 composed samples were prepared so that samples #1, #2 and #3 were taken from plant A and samples #4, #5 and #6 were taken from plant B. The raw material source of all KFM samples was whole Kilka fish. After grinding and mixing the samples, all samples were stored at -20°C until further analysis.

The dry matter (DM) content of each KFM sample was determined by oven drying method at 105°C, ether extract (EE) by Soxhlet's method, crude protein (CP) by Kjeldahl's method, crude fiber (CF) by boiling the sample in 0.255 N sulfuric acid for 30 minutes and then boiling the sample residuals in 0.313 N sodium hydroxide for 30 minutes, and ash by burning the samples in electrical furnace at 450°C for overnight as described by AOAC (1984) procedures. The gross energy (GE) content for each KFM sample was measured by burning the sample in pure oxygen in bomb calorimeter apparatus (Parr 6300, Parr instruments, Chicago, Illinois, USA). In order to measure the mineral contents of the KFM sample, firstly each sample was turned to ash in a porcelain crucible at 450°C and then 30 ml of 2N hydrochloric acid solution was added to each porcelain crucible and placed on a hot plate at 350°C for 2 hours. The porcelain crucible contents were filtered thereafter by Wattman® No. 42 filter paper and transferred to a 100 ml volumetric flask and its volume was reached to 100 ml by adding distilled water. The solution in volumetric flask was used for measurement of mineral content. Calcium, magnesium and all trace elements including iron, copper, manganese, zinc, and selenium were determined by atomic absorption, phosphorus by spectrophotometry, sodium and potassium by flame photometry, chlorine by titration, and sulfur by turbidometry methods (AOAC, 1984). Each sample was examined in six replicates. The data were analyzed in a completely randomized design using the GLM procedure of SAS (SAS, 1999). Comparison of means was conducted by Duncan's multiple range test. Comparison of the average of chemical composition and mineral contents of the KFM samples with values reported by NRC (1994) was conducted using two-sided t-test (Zar, 1996). Univariate and Corr procedures of SAS (SAS, 1999) were used for determination of descriptive statistical parameters and correlation coefficients between chemical composition and gross energy contents of the KFM samples.

3. Results and Discussion

The chemical composition and GE values of the KFM samples are shown in Table 1. The average DM, EE, CP, CF, and ash were 94.76, 23.11, 59.72, 0.67, and 13.05 percent, respectively. The average GE was 5592 Kcal Kg^{-1}. The coefficient of variation of EE, CF and ash were 8.18, 17.91 and 7.59 percent, respectively that were higher, as compared with the coefficient of variation of other chemical composition of the KFM samples. The DM content of the KFM samples varied from 93.88 to 95.73 percent. Al-Noor *et al.* (2023) reported the DM contents of four fish meal samples in the range from 93.82 to 94.89 percent. The average

DM of the KFM samples (94.76%) was significantly higher (P<0.01) than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. Ponce and Gernat (2002) also reported a value of 94.60 percent for the DM of one tilapia by-product meal sample, whereas Anderson *et al.* (1993) reported a value of 95.45 percent for the average DM of six fish meal samples which are significantly higher than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. The EE content of the KFM samples varied from 20.61 to 25.68 percent. Khan *et al.* (2012) reported a variation in EE content from 9.90 to 29.52 percent for 19 fish meal samples. Also, the average EE of the KFM samples (23.11%) was significantly higher (P<0.01) than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals, because fat is not removed from final product in rendering units producing KFM in Iran. The high fat content may be the cause of the relatively higher DM in our KFM samples as compared with those reported by NRC (1994). Although the presence of high fat content can be beneficial in providing energy for animal, however it may facilitates the deterioration of product and reduces its nutritional value. The CP content of the KFM samples varied from 56.95 to 61.81 percent. Al-Noor *et al.* (2023) reported the CP contents of four fish meal samples in the range from 58.43 to 70.60 percent, whereas Khan *et al.* (2012) reported a variation in CP content from 37.49 to 66.57 percent for 19 fish meal samples. The average CP content of the KFM samples (59.72%) was significantly lower (P<0.01) than those reported by NRC (1994) for Anchovy and Herring fish meals but not from Menhaden fish meal. Miller (1970) reported a value of 64.48 percent for the average CP of eight fish meal samples, whereas Ponce and Gernat (2002) reported a value of 63.50 percent for the CP of one tilapia by-product meal sample. The CF content of the KFM samples varied from 0.54 to 0.79 percent. Khan *et al.* (2012) reported the CF content of 19 fish meal samples in the range from 0.12 to 12.67 percent. The average CF content of the KFM samples (0.67%) was significantly lower (P<0.01) than that reported by NRC (1994) for Anchovy fish meal but not from those of Herring and Menhaden fish meals. Similarly, Ponce and Gernat (2002) reported a value of 0.58 percent for the CF of one tilapia by-product meal sample, whereas Sibbald and Wolynetz (1984) reported a value of 0.72 percent for the average CF content of 15 Menhaden fish meal samples. The ash content of the KFM samples varied from 12.01 to 14.21 percent. Al-Noor *et al.* (2023) reported the ash content of four fish meal samples from 12.54 to 20.71 percent, whereas Khan *et al.* (2012) reported a variation in ash content from 12.74 to 28.23 percent for 19 fish meal samples. The average ash content of the KFM samples was 13.05 percent. Anderson *et al.* (1993) reported a similar value of 12.85 percent for the average ash content of six fish meal samples. The GE content of the KFM samples varied from 5394 to 5899 Kcal Kg^{-1}. Khan *et al.* (2012) reported the GE content of 19 samples of fish meal in the range from 4012 to 4776 Kcal Kg^{-1}. The average GE value of the KFM samples was 5592 Kcal Kg^{-1}. Sibbald and Wolynetz (1984) reported a value of 4667 Kcal Kg^{-1} for the average GE of 15 Menhaden fish meal samples and this value is significantly lower than that obtained in the present study. The lower GE values reported by Sibbald and Wolynetz (1984) as compared with our values may be due to the lower EE and higher ash contents of samples analyzed by Sibbald and Wolynetz (1984).

As shown in Table 2, the EE, CP and GE values of the KFM samples decreased as ash content increased. Khatoon *et al.* (2006) also reported adverse relationships between ash and CP and EE contents of 184 fish meal samples produced in Pakistan which are in agreement with the results obtained in the present study. It seems that the ash content is a good indicator for prediction of other chemical composition and gross energy content of the final product.

Table 1
The chemical composition (%) and GE (kcal kg^{-1}) contents of the KFM Samples (as is).

Sample No.	1	2	3	4	5	6	Average	SD[1]	CV[2]	NRC Data for Anchovy Fish Meal	NRC Data for Herring Fish Meal	NRC Data for Menhaden Fish Meal
Dry Matter	95.73	93.88	94.57	94.97	94.09	95.32	94.76	0.78	0.82	92**	93**	92**
Ether Extract	20.61	25.68	23.47	22.54	24.61	21.75	23.11	1.89	8.18	5**	10**	9.4**
Crude Protein	57.98	61.81	61.24	59.36	60.97	56.95	59.72	2.01	3.37	64.2**	72.3**	60.05
Crude Fiber	0.79	0.54	0.61	0.74	0.57	0.77	0.67	0.12	17.91	1**	0.7	0.7
Ash	14.21	12.01	12.65	13.25	12.15	14.03	13.05	0.99	7.59	—	—	—
Gross Energy	5394	5899	5557	5531	5695	5476	5592	194.3	3.48	—	—	—

** Indicating a highly significant difference (P<0.01) between the average nutrient value in KFM samples and that of reported by NRC (1994).
[1]SD = Standard Deviation.
[2]CV = Coefficient of Variation.

Table 2
The correlation coefficients between chemical composition and GE of KFM samples.

	Ether Extract	Crude Protein	Ash	Gross Energy
Ether Extract	1	0.885 (0.0193)*	-0.973 (0.0011)	0.962 (0.0021)
Crude Protein		1	-0.951 (0.0035)	0.798 (0.0570)
Ash			1	-0.892 (0.0170)
Gross Energy				1

* The values shown in parenthesis under the correlation coefficients are significance levels.

The major element contents of the KFM samples are shown in Table 3. The calcium content of the KFM samples varied from 3.56 to 4.27 percent. The average calcium content of the KFM samples (3.92%) was not significantly different from that reported by NRC (1994) for Anchovy fish meal, but was significantly higher ($P<0.01$) than that of Herring fish meal and lower ($P<0.01$) than that of Menhaden fish meal value. Waldroup *et al.* (1965) reported a variation in calcium content from 3.57 to 5.00 with the average value of 4.27 percent for four fish meal samples, whereas Miller (1970) reported an average value of 4.50 with the range from 4.18 to 5.05 percent for calcium content of eight fish meal samples. The phosphorus content of the KFM samples varied from 2.42 to 2.78 percent. The average phosphorus content of the KFM samples (2.58%) was significantly higher ($P<0.01$) than those reported by NRC (1994) for Anchovy and Herring fish meals but was significantly lower ($P<0.01$) than that of Menhaden fish meal. Miller (1970) also reported an average value of 2.56 with the range from 2.33 to 2.88 percent for the phosphorus content of eight fish meal samples, whereas this value was reported 2.57 as an average with the range from 2.29 to 2.88 percent by Waldroup *et al.* (1965) for four fish meal samples, which are higher than those reported by NRC (1994) for Anchovy and Herring fish meals but lower than that of Menhaden fish meal. The sodium content of the KFM samples varied from 0.78 to 0.99 percent. The average sodium content of the KFM samples (0.87%) was significantly higher ($P<0.01$) than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. Anderson *et al.* (1993) also reported a value of 0.89 percent for the average sodium content of six fish meal samples which is higher than those reported by NRC (1994). The potassium content of the KFM samples varied from 0.49 to 0.64 percent. The average potassium content of the KFM samples (0.56%) was significantly lower ($P<0.01$) than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. Anderson *et al.* (1993) reported a value of 0.81 percent for the average potassium content of six fish meal samples which is higher than those reported by NRC (1994) for Anchovy and Menhaden fish meals but lower than that of Herring fish meal value. The chlorine content of the KFM samples varied from 0.57 to 0.78 percent. The average chlorine content of examined samples (0.69%) was not significantly different from those reported by NRC (1994) for Anchovy and Menhaden fish meals but was significantly lower ($P<0.01$) than that of Herring fish meal. The magnesium content of the KFM samples varied from 0.24 to 0.35 percent. The average magnesium content of the KFM samples (0.29%) was not significantly different from that reported by NRC (1994) for Anchovy fish meal but was significantly higher ($P<0.01$) than those of Herring and Menhaden fish meals. Anderson *et al.* (1993) also reported a value of 0.23 percent for the average magnesium content of six fish meal samples. The sulfur content of the KFM samples varied from 0.32 to 0.52 percent. The average sulfur content of the KFM samples (0.43%) was significantly lower ($P<0.01$) than NRC (1994) values for Anchovy and Herring fish meals but was not significantly different from that of Menhaden fish meal.

The trace element contents of the KFM samples are shown in Table 4. The iron content of the KFM samples varied from 188 to 267 mg Kg^{-1}. The average iron content of our samples (223.8 mg Kg^{-1}) was not significantly different from that reported by NRC (1994) for Anchovy fish meal but was significantly higher ($P<0.01$) than Herring fish meal value and lower ($P<0.01$) than that of Menhaden fish meal. Anderson *et al.* (1993) reported a value of 164.5 mg Kg^{-1} for the average iron content of six fish meal samples which is higher than that reported by NRC (1994) for Herring fish meal but is lower than those of Anchovy and Menhaden fish meals. The copper content of examined KFM samples varied from 4.4 to 7.6 mg Kg^{-1}. The average copper content of the KFM samples (5.9 mg Kg^{-1}) was significantly lower ($P<0.01$) than NRC (1994) values for Anchovy and Menhaden fish meals but was not significantly different from that of Herring fish meal.

Table 3
The major element (%) contents of the KFM Samples (as is).

Sample No.	1	2	3	4	5	6	Average	SD[1]	CV[2]	NRC Data for Anchovy Fish Meal	NRC Data for Herring Fish Meal	NRC Data for Menhaden Fish Meal
Calcium	4.27	3.56	3.81	4.02	3.63	4.21	3.92	0.31	7.91	3.73	2.29**	5.11**
Phosphorus	2.78	2.45	2.49	2.61	2.42	2.75	2.58	0.16	6.20	2.43**	1.70**	2.88**
Sodium	0.99	0.78	0.79	0.91	0.81	0.94	0.87	0.10	11.49	0.65**	0.61**	0.65**
Potassium	0.64	0.49	0.53	0.59	0.51	0.62	0.56	0.08	14.29	0.69**	1.09**	0.65**
Chlorine	0.78	0.57	0.71	0.73	0.59	0.76	0.69	0.10	14.49	0.60	0.90**	0.60
Magnesium	0.35	0.26	0.24	0.31	0.27	0.33	0.29	0.04	13.79	0.24	0.15**	0.16**
Sulfur	0.39	0.52	0.48	0.41	0.44	0.32	0.43	0.08	18.61	0.54**	0.69**	0.45

** Indicating a highly significant difference (P<0.01) between the average nutrient value in KFM samples and that of reported by NRC (1994).
[1]SD = Standard Deviation.
[2]CV = Coefficient of Variation.

Table 4
The trace element (mg kg^{-1}) contents of the KFM Samples (as is).

Sample No.	1	2	3	4	5	6	Average	SD[1]	CV[2]	NRC Data for Anchovy Fish Meal	NRC Data for Herring Fish Meal	NRC Data for Menhaden Fish Meal
Iron	267	188	206	234	201	247	223.8	29.57	13.21	220	140**	440**
Copper	7.6	4.4	5.4	6.5	4.6	7.1	5.9	1.32	22.37	9**	6	11**
Manganese	4.6	3.1	3.7	3.9	3.6	4.5	3.9	0.58	14.87	10**	5**	33**
Zinc	95.5	62.3	77.6	81.5	71.8	88.9	79.6	11.23	14.11	103**	132**	147**
Selenium	1.85	1.38	1.68	1.71	1.47	1.77	1.64	0.19	11.59	1.36**	1.93**	2.10**

** Indicating a highly significant difference (P<0.01) between the average nutrient value in KFM samples and that of reported by NRC (1994).
[1]SD = Standard Deviation.
[2]CV = Coefficient of Variation.

Anderson *et al.* (1993) reported a value of 5.1 mg Kg^{-1} for the average copper content of six fish meal samples which is lower than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. The manganese content of the KFM samples varied from 3.1 to 4.6 mg Kg^{-1}. The average manganese content of our studied samples (3.9 mg Kg^{-1})was significantly lower (P<0.01) than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. Anderson *et al.* (1993) reported a value of 11.2 mg Kg^{-1} for the average manganese content of six fish meal samples which is also different from NRC (1994) values. The zinc content of the KFM samples varied from 62.3 to 95.5 mg Kg^{-1}. The average zinc content of the KFM samples (79.6 mg Kg^{-1}) was significantly lower (P<0.01) than those reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. Similarly, Anderson *et al.* (1993) reported a value of 93 mg Kg^{-1} for the average zinc content of six fish meal samples which is lower than those of NRC (1994) values. The selenium content of the KFM samples varied from 1.38 to 1.85 mg Kg^{-1}. The average selenium content of the KFM samples (1.64 mg Kg^{-1}) was significantly higher (P<0.01) than that of NRC (1994) value for Anchovy fish meal but was significantly lower (P<0.01) than those for Herring and Menhaden fish meals.

Generally, the results of the current study showed significant variation in chemical composition and mineral contents among the KFM samples. There were significant differences between the average of each chemical composition and mineral contents of the KFM samples with the values reported by NRC (1994) for Anchovy, Herring and Menhaden fish meals. Therefore, the chemical composition and mineral contents of KFM must be determined firstly before its utilization in livestock, poultry and aquatic diets and the values reported by NRC (1994) can't be used for estimation of chemical composition, mineral contents and thus the nutritional value of KFM.

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