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Determination of selected chemical properties of some oil press biproducts

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Abstract

A selected chemical properties including moisture, ash, carbohydrates, fat, protein and fiber, were studied in sesame, flax, black seed, coconut, star anise and sunflower using cold pressing method. An increase in moisture, ash, carbohydrates, protein and fiber was found after removing the oil. The amount of oil decreased as a result of extraction, the mineral content of the by-products, was also determined (calcium, magnesium, manganese, copper, iron, sodium and potassium), using an atomic absorption spectrophotometer. The defatted flaxseeds had the highest percentage of calcium, magnesium and manganese, compared with the rest of the de-oiled oil crops study. The essential and non-essential amino acids of the de-oiled oil crops were also determined by HPLC.

Keywords: Oil crops, by-products, cold pressing, oil extraction, amino acids, HPLC technology.

I. INTRODUCTION

Oil is extracted by pressing from different oil crops in different ways, including auger, hydraulic pressure or by organic solvents extraction (Fernández-López et al., 2018). Oil extraction produces different types of by-products, characterized by its cheapness compared to its protein content. Such by-products possess many important chemical properties depending on the extraction method used (Prakash et al., 2018). The remaining fat content is also of great benefit, where polyunsaturated fatty acids predominate. The seeds normally contain a high percentage of biologically active compounds, such as polyphenols, known for its antioxidant properties, where after grinding these by-products, defatted flour is produced and used for other purposes (Pardo-Giménez et al., 2012; Pardo-Giménez et al., 2016 ;Al-temimi *et al* .,2020). By- products contain a large percentage of proteins which is a promising sources of human nutrition as substitute to animal protein (Sá et al., 2021).

Recently, the search for and finding sustainable and renewable sources of plant-based proteins has become increasingly important, especially with the growing demand for healthy food category. These products are necessary to avoid obesity, overweight, cardiovascular disease, diabetes and various disorders, which is closely related to improper eating habits and an unhealthy diet (Kotecka-Majchrzak et al., 2020). The food industry concentrates its efforts on developing new products with improved nutritional profiles, by employing the nutritional components recovered from the by-products of oilseed waste, named oilseed press cakes, which are food products after extracting the oil (Kotecka-Majchrzak et al., 2020). These products contain a significant number of proteins, antioxidants and dietary fiber, it consists of polysaccharides and lignin that are neither digested nor absorbed in the human small intestine. The role of these products is to reduce the risk of coronary heart disease and certain types of cancer, according to the recommendations of modern nutrition , The supply of proteins in the diet should be based mostly on vegetable proteins, such as sesame seeds, sunflower seeds, and flaxseeds (Terrien, 2017).

The current study aims to determine the chemical and mineral content, and amino acids in the by-products of oil presses for the production of oil from oily vegetable crops, including sesame, flax, black seed, coconut, star anise and sunflower, which is often disposed of as waste, although it contains high nutritional value. Therefore, we aim to secure a clean environment free of accumulations of these products, as well as its economic and health returns. This is the first attempt to study the chemical properties of some by-products in Iraq which are normally disposed by manufacturers.

II. MATERIALS AND METHODS

Oil crops and oil extraction

The oil crops coming from different sources were obtained from local markets. These include sesame (Afghanistan), black seed (Pakistan), flaxseed (Pakistan), coconut (Indonesia), anise (China) and sunflower (Syria). After cleaning from impurities, the oil extraction process was carried out by cold pressing to obtain by-products separately. The by-products of the studied crops were defatted, grinded, sifted and kept in polyethylene bags until use.

Chemical analysis

Chemical analysis of whole oil crops and powder by-products of oil presses was carried out for sesame, black seed, flax, sunflower, anise and coconut. The percentage of moisture, ash, carbohydrates, fat, protein, fiber, minerals and amino acids was estimated.

Determination of humidity

Humidity was determined according to the standard method mentioned by AACC (2010). Two gm were weighed in a ceramic lid and placed in an electric drying oven at a temperature of 105 °C until the weight was stabilized, the percentage of moisture was then estimated using the following formula:

$$\text{Humidity (\%)} = (\text{Before drying sample weight} - \frac{\text{After drying sample weight}}{\text{Before drying sample weight}}) \times 100$$

Estimation of ash content

Ashes were estimated in the by-products according to the method described in AACC (2010), where 2 gm of the sample was weighed and placed in a ceramic lid and then placed in an incinerator at at a temperature of 557 °C for 6 hours, the percentage of ash was calculated as follows:

$$\text{Ash (\%)} = (\text{Before incinerating sample weight} - \frac{\text{After incinerating sample weight}}{\text{Before incinerating sample weight}}) \times 100$$

Estimation of carbohydrates

The percentage of carbohydrates was calculated by using the following equation (Reference?):

Carbohydrates % = 100 - (Moisture + Ash + Fat + Protein + Fiber)

Estimation of fat ratio:

The fat content of the samples was estimated according to Beshaw et al. (2022), with minor modifications using a continuous extraction device (Soxhlet) with petroleum ether solvent (250 ml solvent and 4 g sample) at 50°C. The fat percentage was calculated as follows:

$$\text{Fat (\%)} = \frac{\text{Fat weight}}{\text{Sample weight}} \times 100$$

Estimation of protein content

The protein content was estimated by calculating the nitrogen content of the by-product powder using Caldall's method. The dry samples were digested with a mixture of Sulfuric acid (H_2SO_4)+ Perchloric acid ($HClO_4$), following Cresser and Parsons (1979). The nitrogen content was estimated by steam distillation and converted to protein as follows:

Nitrogen (%) = (volume of Hydrochloric acid (HCl) consumed× acid molarity × nitrogen equivalent 0.014/sample weight) × 100

$$\text{protein (\%)} = \text{Nitrogen (\%)} \times 5.7$$

Fiber estimation

The fiber percentage of the by-products was estimated according to Madhu *et al*. (2017). A 2 gm of the sample were digested with 1.25% Sulfuric acid H_2SO_4 and 1.25% Sodium hydroxide NaOH to remove fats and then fiber content was calculated as follows:

$$\text{Fiber (\%)} = \frac{\text{Fiber weight}}{\text{Sample weight}} \times 100$$

Estimation of minerals

Calcium, magnesium, manganese, copper, iron, sodium and potassium were estimated in this study according to Cresser and Parsons (1979) with minor modifications. A 0.2 gm of the sample was placed in a 100 ml digestion flask to which 5 ml of concentrated sulfuric acid were added and kept for 24 hours. The flask was placed on heat for 30 minutes, left to coll for 5-7 minutes, and 5 ml of a mixture of 4% perchloric acid $HClO_4$ and 96% concentrated sulfuric acid H_2SO_4 were added returned on heat until it became transparent. The mixture was then filtered and diluted with 50 ml distilled water. The mineral elements were estimated using an atomic absorption spectrophotometer(Atomic Absorption And Photometry Model AA 7000 Shimadzu(Japan)) at the Central Laboratory, College of Agriculture, University of Basrah. The principle of operation of the device is based on the heat emission of combustion vehicles, as a result of these emissions, metallic elements absorb a certain wavelength, according to the method mentioned in Akuru *et al.* (2018). Sodium and Potassium were estimated in the nitrogen digestion solution using the Jenway PFP73 flame photometer.

Amino acids estimation:

Amino acids were estimated in the laboratories of the Ministry of Science and Technology / Department of Environment and Water using the Amino acid analyzer (Korean origin) (Table 1).

Table 1. Working conditions of the Amino acid analyzer.

Device type	Amino acid analyzer-Origination-Korea
Carrier phase	Acetonitrile.Methanol.Formic acid(60.20.20)
Equipped separation column	ZORBAX Eclipse - AAA;3.5mm;Lx i.d.=150x4.6mm
The type of detector used	Florescence (Ex= 445nm , Em= 465nm)
Injection volume	100 uL
The program used	Clarity 2015

Extraction:

The method described in Dahl-Lassen (2018) was followed. To extract amino acids, 3 gm of samples were weighed separately in a volumetric vial of 25 ml capacity with 25 ml of hydrochloric acid (M6) at a temperature of 150 ^{o}C for 3 hours, then dried by rotary evaporator and 5 ml of sodium citrate 2.2 pH was added, it was filtered with a 0.45um plastic filter and injected into the device.

Preparation of the calibration curve

Following Scriver (2001), 0.1 gm of a mixture of amino acids of 99.9% purity was dissolved in deionized water, transferred to a 250 mL conical flask, complete the volume to the mark until the concentration is reached 250 ppm, using the dilution law, the concentrations of the titration curve injected into the Amino acid analyzer were prepared.

Statistical analysis

The statistical analysis was carried out using the ready-made statistical analysis program Release GenStat, depending on the least significant difference between the mean R.L.S.D at the probability level $p<0.05$.

III. RESULTS AND DISCUSSION

Chemical content of the whole and defatted oil crops are shown in Table 2. The moisture percentage of the whole oil crops; sesame, black seed, flax, coconut, anise and sunflower, amounted to 4.92, 5.22, 4.98, 4.79, 4.49 and 5.91%, respectively. The highest percentage of moisture was observed in the whole black seed, followed by the full sunflower with 5.22 and 4.49%, respectively. The results of the moisture content of the black seed were consistent with the finding of Albakry *et al*. indicating that the percentage of humidity was 5.02%. The results are also in accordance with the findings reported by Rosa et al. (2009), who studied the chemical composition of several varieties of sunflower, which ranged 5.65-6.74.

The percentage of ash for vegetable crops, whole black seed and coconut had the highest ash content, which amounted to 4.21 and 4.18%, respectively (Table 2). These results appeared slightly higher than those reported by others (Nergiz and Ötleş 1993; Ghamarnia and Jalili, 2013; Albakry et al. 2022; Ngampeerapong and Chavasit 2019). Such differences might be attributed to watering, extraction process and different estimation procedures.

Results of the chemical composition of the defatted by-products of sesame, black seed, flax, coconut, star anise, and sunflower was studied are exhibited in Table 2. The percentage of humidity amounted to 8.48, 6.73, 6.09, 6.93, 5.74 and 6.38%, respectively. The percentage of ash reached 6.70, 5.20, 5.72, 4.58, 4.61 and 5.42%, respectively. It was noted that the defatted sesame seeds were distinguished by the highest percentage of moisture and ash, which amounted to 8.48 and 6.70%, respectively, compared

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to the rest of the by-products. The results were consistent with Gandhi and Srivastava, (2007) for a study he conducted on the production of protein isolates from defatted sesame flour and its nutritional value, as the percentage of moisture ranged 8.87-10.40, while the percentage of ash was close to what was reached by Hassan (2013), which ranged from 5.11-6.94%, in his study of the chemical content, functional properties, antioxidants and determination of some minerals of defatted sesame seed flour.

The percentage of carbohydrates in anise was characterized by the highest value, followed by black seed, sesame, and flax, which were 41.96, 28.01, 21.97 and 20.22%, respectively (Table 2). These values were lower than other findings of the same crops (Balaji 2008; Madhu et al. 2014; Aglave 2018; Albakry et al. 2022; Kaur et a*l* 2019; Sun et al. 2019; Gai et al., 2023. The reason for such variation is attributed tp several factors including local climatic conditions, pressing techniques, crop genetic variation and estimation methods.

The percentage of carbohydrates increased in by-products of oil crops, anise and defatted Black seed which were distinguished by the highest percentage that amounted to 48.6 and 44.30%, respectively, from the rest of the other by-products. The results were close to what was mentioned by Gökşen and Ekiz (2021), as it ranged between 49.03-49.24, for a study he conducted to use flour by-products to press anise oil in the cold way and use it as a food ingredient in the manufacture of food products.

The percentage of fat in whole crops of whole sunflower recorded the highest percentage of fat, followed by whole (coconut , sesame seed and sunflower) with percentages 49.12, 44.70, 43.58 and 41.89%, respectively (Table 2). The results were similar to a study prepared by Rosa et al . (2009) to determine the chemical composition of varieties of Brazilian sunflower, as the fat percentage ranged between 46.81-51.91%, while the results were higher than those reached by Ngampeerapong and Chavasit, (2019), as the fat percentage ranged from 27.69-31.99% in a study to determine the chemical composition of several varieties of coconut.

We noticed a decrease in the percentage of residual fat after the process of extracting fat using the cold-press method of oil crops, the defatted coconut had the highest percentage of fat, which amounted to 6.98%, and the results were higher than what was reached by Makinde and Eyitayo, (2019), which amounted to 2.92%, who evaluated the chemical composition and functional properties of partial replacement of wheat flour and defatted coconut flour. The variation in the percentage of fat in the oil crops was attributed to the different agricultural conditions such as soil type, climate and different agricultural methods, the method of extracting the fat, the number of extraction times, and the efficiency of the press used to extract the fat from the aforementioned oil crops (Hewitt and Novaes, 2020).

One of the advantages of de-oiling oil crops is the high protein content of the product (Prakash et al. 2018). We noted that whole coconut has the highest percentage of protein, which was 25.34%, while whole star anise has the lowest percentage, which amounts to 19.52%. The results of the protein percentage of coconut did not agree with Mahayothee et al. (2016) for a study of the chemical content of coconut at different stages of maturity, which ranged between 2.71-4.49%. Also, the results did not agree with Chempakam and Balaji, (2008) in his study of the percentage of star anise protein, as it reached 4.25%.

The highest protein percentage in the by-products was in the defatted sunflower seeds, which amounted to 48.85%, followed by defatted sesame and then defatted coconut. The results were higher than what was mentioned by de Oliveir Filho and Egea, (2021) for a study conducted by the by-products of sunflower seeds and their uses for many applications in the field of food and their ability to improve the nutritional and functional value of foods.

Fibers percentage was higher in whole anise and whole flax seed compared to the rest of the oil crops, reaching 8.91 and 8.56%, respectively (Table 2). The results of the percentage of anise fiber were less than what was mentioned by Xu et al. (2022); Chempakam and Balaji (2008), with 11.12 and 9.38-11.93%, respectively, while the results agreed with Hussain et al. (2006) for his study of the physical, chemical and sensory characteristics of full-fat flax seeds, which amounted to 8.2%(Hewitt and Novaes, 2020). These variations are attributed to the different exctraction techniques, efficiency of the press instruments and different plat varaities.

The defatted flax (DFS) and star anise (DA) were distinguished by the highest percentage of fiber, which amounted to 15.67 and 15.50% (Table 2). The results did not agree with Cohen et al. (2013) for a study that evaluated the effect of whole and defatted flax seeds on satiety levels, which ranged 6.2-7.8%, also, the results of the percentage of fiber for defatted star anise DA did not agree with the results of Gökşen and Ekiz (2021), which ranged between 12.64-13.14%.

The difference in the chemical content of moisture, ash, carbohydrates, fat, protein and fiber between oily and defatted crops may be attributed to the difference in the chemical content between the same type among the aforementioned crop varieties which might be attributed to the difference in environmental conditions, cultivation mechanism, and the nature and type of fertilizers used. Their effect on the chemical properties of the plant, as well as the different varieties used and the extent of plant exposure to damage resulting from plant diseases (Alzamel et al., 2022; Radić et al., 2008; Millar et al., 2014). The results of the statistical analysis showed that there are significant differences in the chemical composition of the oil crops at the probability level ($P<0.05$).

Table 2. The chemical composition of whole and defatted oil crops.

T		Moisture	Ash	CHO	Fat	Protein	Fiber
Sesame	WSS	4.92	3.68	21.97	43.58	19.64	6.21
	DSS	8.48	6.70	25.22	3.92	45.87	9.13

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Black seed	WBB	5.22	4.21	28.01	35.21	22.34	5.01
	DBB	6.73	5.20	44.3	3.18	29.56	10.54
Flaxseed	WFS	4.98	3.8	20.22	41.89	20.55	8.56
	DFS	6.09	5.72	28.3	3.01	41.03	15.67
Coconut	WCO	4.79	4.18	14.23	44.7	25.34	6.76
	DCO	6.93	4.58	15.0	6.98	45.05	14.50
Anise	WA	4.49	3.98	41.96	21.14	19.52	8.91
	WS	5.74	4.61	48.6	2.14	20.89	15.50
Sunflower	WSF	5.91	3.43	15.9	49.12	21.33	4.31
	DSF	6.38	5.42	19.88	4.90	48.85	14.12

The results are average of three replicates, W stands for whole oil crop, D stands for defatted oil crops.

Determination of mineral content

Table 3 shows the mineral content of calcium, magnesium, manganese, copper, iron, sodium and potassium in the by-products of the oil presses of the oil crops, which include sesame, black seed, flax, coconut, anise and sunflower. The defatted flaxseed had the highest percentage of calcium, magnesium and manganese, which amounted to 546.23, 454.87 and 7.87 gm / 100gm, respectively. The results did not agree with Hussain et al. (2008), as the percentage of calcium was 398.21 gm / 100gm, while the percentage of magnesium was less than what the researcher reached, which amounted to 713.04 g, / 100 gm. As for manganese, it was less, as the percentage of manganese was 4.73 gm / 100 gm in a study conducted by the chemical composition of whole and defatted flax seeds.

The percentage of copper in the by-products of the black seed had the highest value, which amounted to 7.87 gm / 100 gm, compared with the rest of the by-products. It was followed by defatted flaxseeds at a rate of 4.23 gm / 100gm. The results were much lower than what Mariod et al. (2012) reached, as it amounted to 0.094 gm / 100 gm in his study of the chemical composition of the black seed and the effect of germination, while the results were somewhat similar to what Hussain et al. (2008) reached, which amounted to 3.45 gm / 100 gm. (Hewitt and Novaes, 2020). The use of different fertilizers and the type of soils might the reason behind such variations.

The value of iron in the oil crops, and the defatted anise had the highest value among the rest of the defatted oil crop varieties, which amounted to 20.12, it was followed by defatted flax seeds, which amounted to 15.34 gm / 100 gm. These results did not agree with the findings of Angami et al. (2021), which amounted to 147 points in his study of the chemical properties and nutritional value of star anise. As for the value of iron in flax, it was higher than what was reached by Sibt-e-Abbas et al. (2020), which amounted to 7.21 gm / 100 gm for a study conducted by it to identify and study the functional and nutritional characteristics of defatted oilseeds.

The highest value for sodium was for the defatted sesame seeds, which amounted to 687.33gm/100gm, as for the lowest value, it was for defatted coconut, which amounted to 249.40 gm / 100 gm. The sodium value in sesame was lower with the conclusion of Abbas et al. (2022), who studied the nutritional and therapeutic properties of whole and defatted sesame seed flour, as the sodium percentage reached 133.88 gm / 100 gm.

The values of potassium were for the seeds of black seed and flax, defatted the highest value of potassium, which amounted to 922.21 and 856.67 gm / 100 gm, respectively, while the results were higher with the findings of Albakry et al. (2022), which amounted to 716.47 for his study to evaluate the nutritional quality and biologically active properties of black cumin seeds. As for the value of potassium in flax, it was lower than the result reached by Sibt-e-Abbas et al. (2020), as it reached 1430.14, to study the nutritional and functional characterization of protein isolates from defatted oilseeds.

The reasons for the difference in the mineral content of calcium, magnesium, manganese, copper, iron, sodium and potassium, among the defatted oil crops and the defatted oil crops dealt in several studies might be due to type of fertilizers used, the method of fertilization, climatic factors, the amount of organic and mineral materials of the soil, and the vital factors, it also affects the method and number of times the oils are extracted (Alzamel et al. (2022). The results of the statistical analysis showed that there are significant differences in the mineral content of oil crops at the probability level ($P<0.05$).

Table 3. The content of minerals in the by-products of oil presses of oil crops gm/100 gm.

Samples	Calcium	Magnesium	Manganese	Copper	Iron	Sodium	Potassium
Sesame	412.01	326.43	6.98	2.32	4.01	687.33	598.65
Black seed	424.54	201.32	3.93	7.87	6.17	392.34	922.21
Flaxseed	546.23	454.87	7.59	4.23	15.34	457.10	856.67
Coconut	321.55	215.51	2.31	0.33	2.52	249.40	440.21
Anise	173.87	121.83	1.12	0.94	20.12	265.71	219.11
Sunflower	142.37	153.12	2.01	2.12	5.16	320.73	581.40

Estimation of amino acids

Results of the amino acids in the studied material are shown in Table 3 and Figures 1,2,3,4,5 and 6. These amino acids include essential and non-essential types including threonine, methionine, leucine, tryptophan, cysteine, phenylalanine, alanine, glutamic acid, arginine, proline, serine and glycine. The black seed was superior in its content of threonine, methionine, tryptophan, phenylalanine, glutamic acid, arginine, and serine which amounted to 12.45, 30.23, 8.65, 15.23, 12.3, 6.58, 41.25 mg / 100 gm protein, respectively (Figure 3). The black seed contains 17 essential and non-essential amino acids including valine, lysine, histidine, tyrosine, and aspartic acid, the highest percentage of the amino acid was glutamic acid, which was 4.10 gm / 100 gm, then the amino acid aspartic acid 1.59 gm/100gm, it was followed by arginine, leucine, and glycine (1.40, 0.93, 0.91) gm/100gm.

The defatted sesame seeds possessed the highest percentage leucine (8.05 mg / 100 gm), alanine (12.54 mg / 100 gm) and proline (13.22 mg / 100 gm) (Table 4, Fig. 1). In addition, arginine was also high and amounted to 26.33 gm / 100 gm of protein. These results did not agree with Melo et al. (2021), who showed that defatted sesame seeds (sesame cake) contain 18 amino acids, glutamic acid had the highest percentage (61.93 mg / 100 gm), followed by arginine, aspartic acid, leucine, serine, and valine, which reached 48.31, 26.20, 20.70, 15.20 and 13.09 mg / gm, respectively.

The defatted flax seeds had the highest percentage of glycine (12.26 gm / 100 gm) of protein, as well as the high percentage of arginine (19.23 gm / 100 gm) of protein, as it is considered the third largest content of arginine after black seed and sesame (Fig. 2). Alanine, serine, and glycine formed ratios of 3.30, 3.17 and 3.09 gm/100 gm of the total non-essential amino acids, while the highest percentage of essential acids was for lysine, which was 4.37 gm /gm 100 g protein of the total amino acids. The aromatic acids phenylalanine and tyrosine gave a ratio of 3.30 gm/100 gm protein, followed by valine, threonine, isoleucine, sulfur-containing acids (methionine, cysteine, tryptophan, histidine and lysine), with ratios of 2.60, 2.49, 2.12, 2.00, 1.96, 1.67 and 1.62 gm/100 gm protein, respectively. Thus, defatted sesame, black seed and flax seeds have the highest percentage of amino acids compared to coconut, star anise and sunflower.

Threonine, methionine, leucine, cysteine, phenylalanine, alanine, glutamic acid, arginine, proline, serine, chlorine were higher in the defatted sun flour seeds than in coconut and anise, with ratios of 7.00, 3.77, 12.50, 2.66, 6.54, 8.85, 8.44, 3.58, 18.28, 6.21, 8.91 and 8.12 respectively, it was higher for arginine and leucine (Figure 6). The results did not agree with Ugolini et al. (2015), who showed that the highest percentage of glutamic acid was 14.38, and that of arginine was 11.84. The reason is due to the difference in the proportions of amino acids in sesame, black seed, flax, coconut, star anise, sunflower defatted, due to the different cultivation conditions, the fertilizers used, the different varieties and the methods used to remove the fat.

Table 4. Determination of amino acids for some defatted oilseeds mg/100g.

Amino acid	Sesame	Black seed	Faxseed	Coconut	Anise	Sunflower
Threonine	3.22	41.25	7.82	1.25	1.25	7.00
Methionine	5.90	6.58	3.71	2.33	3.55	3.77
Leucine	13.22	8.12	12.55	2.89	2.56	12.50
Tryptophan	3.98	12.3	3.12	1.47	3.48	2.66
Cysteine	2.56	6.23	3.55	2.66	2.17	6.54
Phenylalanine	5.92	15.23	9.60	2.89	2.66	8.85
Alanine	12.45	10.49	9.33	3.05	1.88	8.44
Glutamic acid	6.56	8.65	6.55	0.14	2.36	3.58
Arginine	26.33	30.23	19.23	2.32	4.58	18.28
Proline	8.08	6.99	2.56	0.55	2.33	6.21

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Serine	9.05	12.45	9.55	0.97	1.89	8.91
Glycine	12.25	4.55	12.26	1.66	1.97	8.12

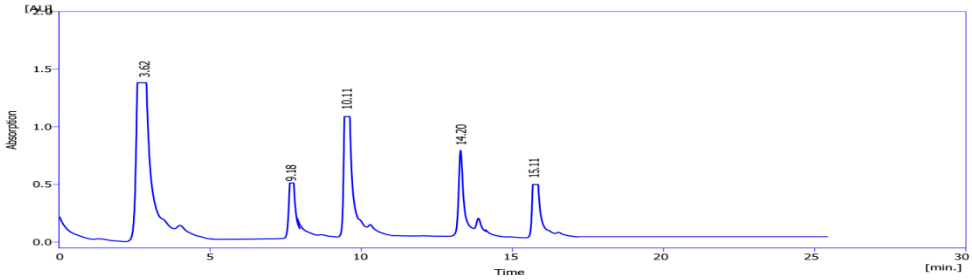

Figure 1. High-performance liquid chromatography (HPLC) of amino acids in defatted sesame powder.

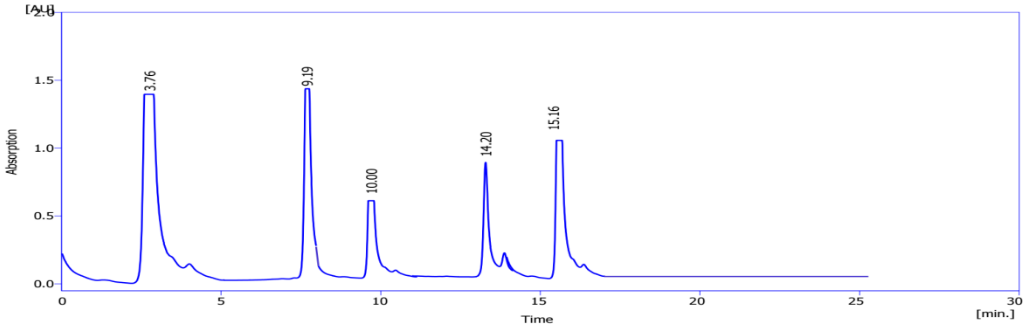

Figure 2. High-performance liquid chromatography (HPLC) of amino acids in defatted flaxseed powder.

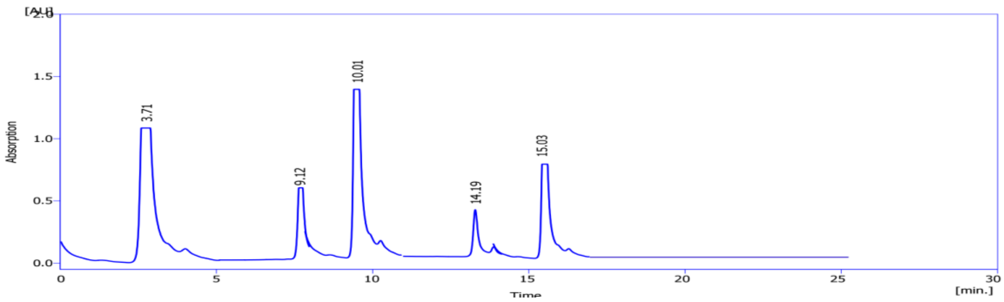

Figure 3. High-performance liquid chromatography (HPLC) of amino acids in defatted black seed powder.

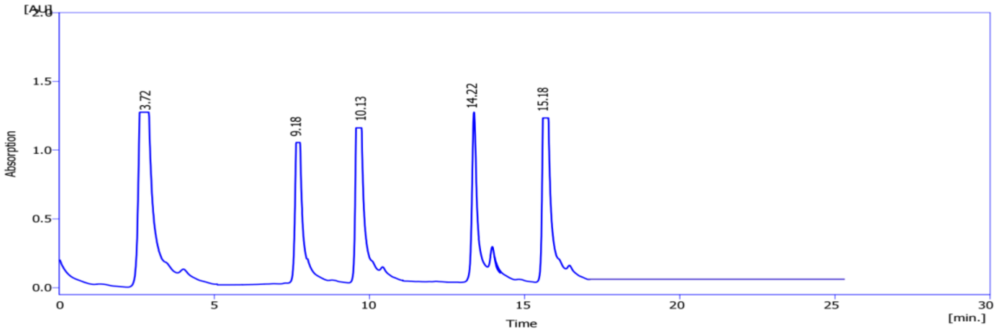

Figure 4. High-performance liquid chromatography (HPLC) of amino acids in defatted coconut powder.

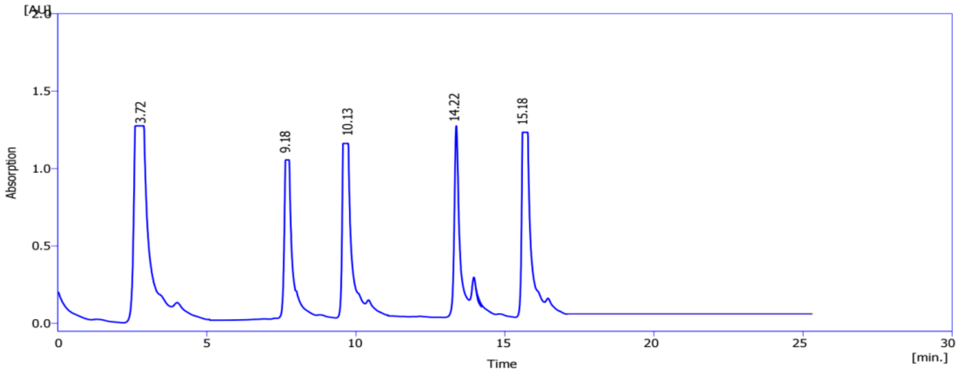

Figure 5. High-performance liquid chromatography (HPLC) of amino acids in defatted star anise powder.

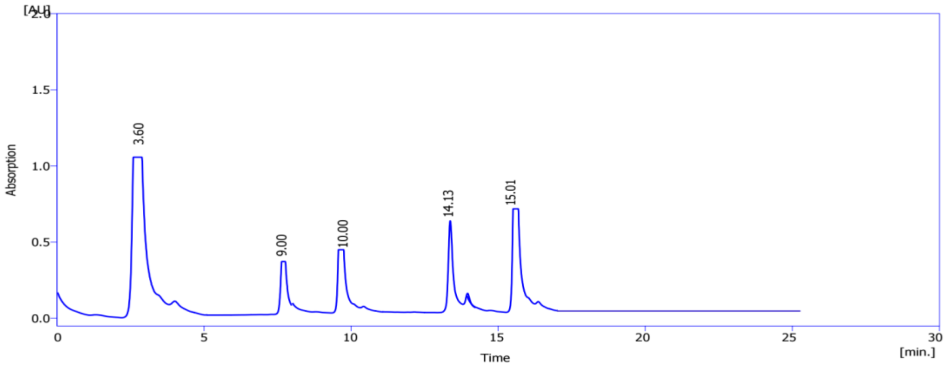

Figure 6. High-performance liquid chromatography (HPLC) of amino acids in defatted sunflower powder.

IV. CONCLUSION

In the current study, we proved the nutritional value and chemical content of the by-products of sesame, flax, black seed, coconut, anise and sunflower before and after extracting oil by cold press. Such products are not disposed in Iraq and do not utilized in any food industry. The significant high content in the percentage of carbohydrates, protein and fiber as well as high mineral content, especially in flax flour defat, make by-products important to be used in various foods produced in the country. In addition, we observed considerable concentration of essential amino acids in the crops studied. We recommend using such by-products by food manufacturers instead of wasting them.

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