



A bi-annual journal published by the Faculty of Science, University of Lagos, Nigeria

<http://jsrd.unilag.edu.ng/index.php/jsrd>

Quality assessment of edible oil and animal feed from seeds of sesame (*Sesamum indicum* L.) grown in Nigeria

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(Received 21 July 2025/Revised 07 October 2025/Accepted 14 October 2025)

Abstract

This study focuses on the extraction, characterization and quality assessment of sesame seeds for edible oil production, and the conversion of sesame waste into a nutritious animal feed supplement. The study analyzed the proximate composition of sesame seeds and waste, as well as their crude fibre, fat, protein, ash, moisture, and carbohydrates, the presence and levels of essential minerals such as calcium, magnesium, sodium, zinc and iron, the levels of heavy metals (Arsenic, Copper, Lead, Mercury, Cadmium and Iron) as critical steps in ensuring their suitability for human and animal feed. Prescribed analytical procedures were employed to determine the physicochemical properties and mineral content of the sesame oil and waste, including: Soxhlet extraction for oil extraction, Kjeldahl method for protein analysis, gravimetric method for moisture and ash content determination. Inductively Coupled plasma (ICP) spectroscopy for mineral and heavy metal analysis. The results showed that the proximate analysis of the sesame seeds contains 57.5% oil, 20.58% carbohydrates, and 3.194% moisture, making them suitable for edible oil. Sesame waste was found to contain 36.87% protein, 9.6% crude fiber, and 10.25% oil, indicating its potential as animal feed supplement. Heavy metal analysis detected Fe and Cu at concentrations of 0.0120 mg/L and 0.0075 mg/L respectively, while other metals were below the limit of detection (>0.001 mg/L). The results revealed that sesame seeds and its oil can be used as an alternative supplement of protein and minerals. The sesame waste is a good source of essential mineral which are vital for healthy digestion, animal growth and development. These findings highlight the nutritional value of sesame seeds and waste for various applications.

Keywords: sesame seeds, proximate analysis, mineral composition, inductively coupled plasma, Physicochemical parameters.

Introduction

Sesame seeds (*Sesamum indicum* L.) are one of the oldest cultivated crops in the world, with a history dating back over 3,000 years. It is a common food in diets because it is widely cultivated, has a mild flavor, and is high in nutrients. Rich in fats and protein, sesame seeds offer numerous health advantages. (Wei et al. 2022) Sesame seeds originated in Africa and

were introduced to India and Asia over 2,000 years ago. Today, they are grown in many parts of the world, with India, China, and Africa being the top producers. Sesame seeds are a good source of: - protein (20-25%), oil (40-50%), fiber (5-10%), vitamins (B1, B2, B3, B5, B6, and C), minerals (calcium, magnesium, phosphorus, potassium, and iron (Abass et al., 2022).

Sesame seeds have various uses: Used as a condiment, ingredient in baking, and as a topping for salads and bread, cosmetics, and industrial applications, used in the production of soap, paint, and lubricant. Sesame seed processing generates significant amounts of waste, including: seed coats, oil cake, and hulls (Abass et al., 2022). These waste products can be utilized as biofuels, reducing waste and increasing the crop's overall value. Sesame seed cultivation has a relatively low environmental impact compared to other crops, as it requires minimal water and pesticides. However, the processing and transportation of sesame seeds can have negative environmental impacts if not managed sustainably.

Despite the growing demand for sustainable and environmentally friendly animal feed and edible oil, the processing of sesame seeds generates significant amounts of waste (seed coats, oil cake, and hulls) that are often underutilized or discarded, contributing to environmental pollution and waste management challenges. Meanwhile, the animal feed and edible oil industries face challenges in meeting the growing demand for nutritious and sustainable products (Dai et al., 2016)

The disposal of sesame seed waste poses environmental and economic challenges. The waste is often discarded in landfills, contributing to greenhouse gas emissions and waste management issues. Furthermore, the waste has the potential to be converted into valuable products, which could generate income and employment opportunities (Dai et al., 2016). The aim of the study is to add value to the sesame seed waste to produce quality animal feed and edible oil.

Materials and Methods

Materials

Potassium hydroxide, Sodium thiosulfate, potassium iodide, Wijs solution (Iodine monochloride in acetic acid), carbon tetrachloride, n-hexane, petroleum ether, ethanol, starch, sodium hydroxide, sulfuric acid, boric acid solution, hydrochloric acid, Magnesium standard solutions, Lanthanum chloride solution (10% w/v), and Nitric acid (HNO₃), were sourced commercially in Lagos, Nigeria.

Extraction of the oil and animal feed from the sesame seed waste

The seed wastes were cleaned, dried and the oil was extracted out by Soxhlet extraction process. It is a continuous, automated process that ensures efficient extraction using suitable solvent. The animal meal thus obtained was freed from residual oil by solvent extraction. The residual oil was extracted in a Soxhlet apparatus with n-hexane (Yeasmin, et. al., 2021).

Characterization of the extracted oil and animal feed

Physicochemical analyses of the oil were determined as follows:

Physical properties such as moisture content, refractive index, density, specific gravity and viscosity of the oil were determined by the method described by Vogt, et al. (2021) and AOAC (1995). Acid value, saponification value, iodine value, peroxide value, unsaponifiable matter and free fatty acid were estimated according to the AOAC (1999).

Animal feed analysis (Sesame seed waste)

The defatted seed animal meal was air dried, and analysis of nitrogen was carried out by Micro-Kjeldhal method, and the percentage of protein was calculated (AOAC, 1990). The defatted meal was also used for different analysis like ash (ATM D586-97, 2002), fiber (AOAC, 1980), carbohydrate (Anon, 1955), residual fat (Folch, et., al1957) and moisture content (Vogt et al., 2021). The minerals such as calcium, potassium, phosphorous, magnesium, sodium and iron were determined by atomic absorption spectroscopy (Model: AA-68000, Shimadzu, Japan) coupled with an auto-sampler (ASC- 6100). The fatty acid composition of the sesame oil and the chemical compound of seed meal were analyzed by SHIMADZU GC-2010 was equipped with auto-sampler (AOC- 20s), auto-injector (AOC-20i) and SH Rxi 5MS Sill capillary column with 30m×0.25mm×0.25 µm film. Detection of aflatoxin in seed meal was done following the method of Osweiler et al. (2013).

Results and Discussion

Results of proximate analysis parameters of edible oil from sesame and its waste

The Proximate analysis characterizations of the Sesame and Sesame waste samples are presented in Table 1. The Purity value of the Sesame seed recorded was 99.98%. This purity

value for the sesame seeds was above the NIS permissible limit (99.0 % Max). The Moisture content of the sesame seed was 3.194%. This indicated the moisture content for sesame seed was within the NIS 580:2013 permissible limit (6.0%). Refractive index is used mainly to measure the change in unsaturation as the fat or oil is hydrogenated. The refractive index of oils depends on their molecular weight, fatty acids chain length, degree of unsaturation and degree of conjugation.

The refractive index of the sesame seed was 1.472, there is no limit stated. The value of the Sesame seed density recorded was 632.65kg/m³ which is above the permissible limit of the NIS 580:2013 (570 kg/m³ min.). The Specific

Gravity Value for sesame seed was 0.917, the NIS permissible limit was not stated. The Viscosity Value of the sesame oil recorded @ 40°C was 38 cSt, there is no limit stated by NIS 580:2013. The Acid value is an indication of the amount of fatty acid present in the oil sample. It is also a reflection of pH value of oil that is as the acid value increases the pH of oil decreases.

The recorded acid value was 1.08 mg KOH/g, the NIS permissible limit was not stated. Saponification is an indicator of average molecular weight and, hence chain length. It has an inverse relationship with molecular weight of lipids. The sesame seed saponification value recorded was 175.75 KOH/g, there is no limit stated by NIS 580:2013.

Table 1 Proximate analysis of sesame seed and oil

Sesame Seed and Sesame Oil Analysis			
S/N	Parameter	NIS 580:2013 Specifications	Sesame seed result
1	Purity (%)	99.0% Max.	99.98
2	Moisture content (%)	6.0% Max.	3.194
3	Refractive Index @ 25°C	Not stated	1.472
4	Density (kg/m ³)	579.0 Min.	632.65
5	Specific Gravity @ 20°C	Not stated	0.917
6	Viscosity of the oil @ 40°C	Not stated	38 cSt
7	Acid value (mg KOH/g)	Not stated	1.08
8	Saponification value (KOH/g)	Not stated	175.17
9	Iodine value (%) per 100g	Not stated	98.71
10	Peroxide value (MEQ/kg)	10.0 Max.	3.17
11	Unsaponifiable matter	Not stated	2.2
12	Oil content (%)	35.0% Min	57.5
13	Free acid (%)	1.0 Max.	0.54
14	Carbohydrate	Not stated	20.58

The iodine value recorded for the sesame seed per 100 g was 98.71%, the NIS permissible limit was not stated. The iodine value in the sesame oil shows the presence of unsaturated fatty acid. It indicates the degree of unsaturation in the fatty acids of tri-acyl glycerol. This value could be used to quantify the amount of double bonds present in the oil, which signifies the susceptibility of oil to oxidation. The value recorded for peroxide in the sesame seed was

3.17 MEQ/kg, the value was within the permissible limit of the NIS 580:2013 (10 MEQ/kg max.). The Sesame seed Unsaponifiable matter value was 2.2, there is no limit stated by NIS 580:2013. The value for oil content recorded for the sesame seed was 57.75%, this was higher than the NIS 580:2013 permissible limit of 35% min. The free fatty acid (FFA) of the sesame seed recorded was 0.54% this was within the range of the

permissible limit of the NIS 580:2013 (1% Max). The value of the carbohydrate recorded for the sesame seed was 20.58 kcal, there is no limit stated by NIS 580:2013.

Proximate analysis parameters of sesame seed waste (animal feed)

The proximate composition of the sesame seed waste is presented in Table 2. The results indicated that the sesame seed waste contained 3.69% nitrogen, 16.87% protein, 2.25% ash content, 9.6% crude fibre, 5.5% carbohydrate, 0.05% residual fat, 4.47% moisture content, 10.25% oil content, 3.28% free fatty acid,

1.01% calcium, 1.43 % potassium, 1.22 % phosphorus, 1.29 % magnesium, 2.91 % sodium, 0.40 % iron and 64.5 ppb aflatoxin.

The nitrogen content value of 3.69% was recorded in this study which is within the optimal nitrogen content range in sesame waste (3 - 6) % max. This implies that the sesame waste can be used as organic fertilizer, composting and in biogas production. It also serves as animal feed and helps to support plant growth. The nitrogen content value was in compliance with waste management and environmental regulation.

Table 2 shows the comprehensive analysis of sesame seed waste

Comprehensive Analysis on Sesame seed waste (sludge) Report			
S/N	Parameter	FAO Specifications	Sesame Seed Result
1	Appearance	Brown	Brown
2	Nitrogen content (%)	4 – 7%	4.69
3	Protein (%)	15 – 30%	16.87
4	Ash (%)	5 – 10%	4.25
5	Crude fiber (%)	10 – 15%	9.6
6	Carbohydrate (%)	20 – 40%	5.5
7	Residual fat (%)	5 – 10%	0.05
8	Moisture content (%)	10% max.	4.49
9	Calcium content (%)	0.5 – 1.5%	1.01
10	Potassium content (%)	1.2 – 2.5%	1.43
11	Phosphorus content (%)	1.0 – 2.5%	1.22
12	Magnesium content (%)	0.5 – 2.0%	1.29
13	Sodium content (%)	0.5 – 2.5%	2.91
14	Iron content (%)	0.5 – 1.0%	0.40
15	Oil content (%)	5 – 10%	10.25
16	Fatty acid (%)	10% max.	3.28
17	Aflatoxin content (ppb)	20ppb max.	18.5

The protein content in sesame waste analyzed was 16.87% which is in conformance with regulation standard (15 -30) %. The high protein content shows that it can be applied in animal feed, aquaculture feed, cosmetics, pharmaceuticals and biodegradable materials. The ash content of sesame waste was 4.25%, lower than the value of 9.68 reported by Teferi et al., (2013). The lower ash content increases the protein and oil concentration thereby improving the nutritional value and enhancing the animal feed quality. The crude protein value

of 9.6% recorded in this study was higher than the 5.44% reported by Tereri et al., (2013). The slight difference observed might be attributed to varietal and geographic differences. The high crude fiber suggest that sesame capsules can serve as a good source of fiber and energy for animals. Dietary fibers have been reported to be beneficial in stimulating gut health, increasing satiety, affecting behavior, and overall well-being (Bach et al., 2012, Wenk, 2001, De Leeuw et al., 2008, De Lang et al., 2010). This may be attributed to varietal differences.

The carbohydrates values recorded in this study was 5.5% lower than the regulatory compliance; the difference maybe as a result of the sesame seed varieties, inefficient processing and contamination.

The value for oil content recorded for the sesame waste was 10.25%, the value was within the range of the NESREA permissible limit of 10 -15 % max. The free fatty acid value was 3.28% which was within acceptable range of the waste management and environmental regulation standard of 5% max. This recorded free fatty acid shows the oil stability and the sesame waste can be used as animal feed. The moisture content value of the sesame waste (sludge) was 4.49%. This result shows that the low moisture content compared to the waste management and environment regulation (10 - 15) %. This implies that the sesame sludge requires minimal energy for efficient drying and processing. Minerals are required in small amounts, to make the body function properly. Minerals are essential in meeting the essential nutritional needs of humans. They regulate water retention and maintenance for the activation of various metabolic processes within the body.

The functional roles of these elements (sodium, potassium, calcium, magnesium, zinc and iron) are well documented but must be taken appropriately to meet the daily requirement. The concentration of the essential metal detected in this study was 1.01 % calcium, 1.43 % potassium, 1.22 % phosphorus, 1.29 % magnesium, 2.91 % sodium, 0.40 % iron were all within the acceptable limit of the NESREA which shows the sesame seed waste is in compliance with regulations, optimizes nutrient content, enhances product quality and supports environmental sustainability. Sodium is an essential mineral that regulates blood volume, blood pressure, osmotic equilibrium and pH. Excess sodium has direct adverse effect on target organs, beyond the increased risk of hypertension (HTN). These values obtained agreed with those reported by Bedigian et al. (1985) and Njoku et al. (2010). The next abundant mineral element was phosphorus which recorded the value of 1.02+ 0.0 ppm. This value is lower when compare with the value reported for melon oil seed (Fagbemi, 1991) and equivalent to the data obtained by Njoku et al. (2010). It has been reported that magnesium

serves as an activator of many enzyme systems and maintains electrical potentials in nerves (Abass, et al., 2021).

Calcium in conjunction with phosphorus, magnesium and nitrogen are all involved in bone formation (Aremu et al., 2006). The aflatoxin analysis in sesame sludge is crucial due to food safety and human health risks, animal health and productivity impacts, regulatory compliance requirements. The level of aflatoxin detected in the sesame waste sample was 64.5 µg/kg which was higher the environmental regulations NESREA acceptable limit of 10 ppb due to inadequate drying, poor storage conditions and aflatoxin resistant sesame varieties. This might pose a lot of deficiency such as reduction in animal growth rates, reduces feed efficiency, increase disease susceptibility, reproductive problems and contamination of other food products.

Moisture content, viscosity and refractive index of sesame oil were determined and depicted in Table 1. All values were within the WHO/FAO permissible limits. The results showed in Table 2 that the free fatty acid, ash content, nitrogen content, carbohydrate, crude fibre, residual fat and protein percentage of sesame oil were 3.28%, 2.25%, 4.69%, 5.5%, 10.25% and 16.87%, respectively. These results were similar to those reported in other studies, Abass et al (2021). It was found that the nitrogen content of sesame waste was 6.0%, the carbohydrate content was 8.0% and the percentage of protein content was the highest, 50.0%. The content of crude fiber was 13.0% whereas moisture, ash and residual fat content were 6.0%, 3.0% and 14.0%, respectively. All values were within the FAO acceptable limit. Sesame meals contain good percentages of minerals which may add better nutritional value for foods or in animal feed formulations.

Micro-elements play important roles in chemical, biological, biochemical, metabolic, catabolic and enzymatic reactions in the living cells of plants, animals and human beings. Among these, Magnesium acts as a cofactor for over 300 enzymatic reactions, including those involved in DNA and RNA synthesis, protein production, and cellular repair. Calcium acts as a signaling molecule for nerve transmission, allowing messages to pass between neurons. Iron is vital in oxygen transport and enables metabolism. (Gebrekidan and Desta, 2019).

Results of the determination of heavy metals in sesame oil

Table 3: Determination of heavy metals in Sesame Oil

S/N	Test Parameters/Units	Results	Limit of Detection	Codex Stan 193-1995 (Codex General Standards)
1	Arsenic (mg/kg)	Less than 0.0001	0.0001	0.1
2	Copper (mg/kg)	0.0075	0.0001	0.5
3	Lead (mg/kg)	Less than 0.0001	0.0001	0.1
4	Mercury (mg/kg)	Less than 0.0001	0.0001	0.1
5	Cadmium (mg/kg)	Less than 0.0001	0.0001	0.05
6	Iron (mg/kg)	0.0120	0.0001	5.0

Heavy metals enter and contaminate the human body through food chain and the presence of heavy metals in sesame seed oil can cause oxidative deterioration and adverse effects on the shelf life. The heavy metal uptake through food chain is related to the heavy metals concentration and the amount consumed of in sesame seed (Kheirat et al 2021).

In the present study, the concentrations of the trace essential elements (copper and iron) and non-essential toxic heavy elements (cadmium, arsenic, lead and mercury) in the sesame oil samples were analyzed via ICP-OES. The elements were extracted by treating the industrial sesame oil samples with diluted nitric acid. Table 3 shows the results of the analyses. In general, the presence of excessive amounts of heavy metals is unacceptable since they could be toxic and oxidative to consumers, thereby facilitating the degradation of oil and decreasing its shelf life. Iron in the human body act as a catalyst and in the absence of enzymatic catalyst most biochemical reactions are so slow and would not occur under mild conditions of temperature and pressure that is compatible with life (Gebrekidan and Desta, 2019) Sesame seeds contain Fe which are consumed without any health problem. Copper is responsible for

normal biological activities and it is therefore important to consume a certain quantity of copper to maintain the human health (Gebrekidan and Desta, 2019). Essential trace elements (Fe and Cu) are components of proteins, enzymes and redox system for the human body system. Deficiency or excessive consumption of these metals (Fe and Cu) in the human body system which can lead to different disorders or diseases (Hu and Zhou 2019). Pregnant and breast-feeding women are required to consume 11 and 12 mg/day Cu, respectively and the Cu is used for different biochemical processes (Xiang et al 2011). At higher concentrations, essential heavy metals are toxic and would affect soft tissues particularly blood and kidneys. In the present research, lead, cadmium, arsenic and mercury were not detected in the examined sesame oil samples. In addition, no significant difference was observed in the toxic heavy metal content of the sesame oil as the result shows that nonessential toxic heavy metals were below the limit of detection <0.001mg/kg. it guarantees the safe consumption of the sesame oil without significant health on the consumer. All the toxic heavy metals in the sesame seed falls with the permissible limit of CODEX standard (Codex Alimentarius, 2001).

Table 4: Determination of heavy metals in sesame waste

S/N	Test Parameters/ Units	Results	Limit of Detection	Codex Standard
1	Arsenic (mg/kg)	Less than 0.0001	0.0001	1.0
2	Copper (mg/kg)	0.0125	0.0001	2.0
3	Lead (mg/kg)	Less than 0.0001	0.0001	1.0
4	Mercury (mg/kg)	Less than 0.0001	0.0001	0.1
5	Cadmium (mg/kg)	Less than 0.0001	0.0001	0.05
6	Iron (mg/kg)	0.1588	0.0001	5.0

In the study, lead, cadmium, arsenic and mercury were not detected in the examined sesame waste samples and no significant difference was observed in the toxic heavy metal content of the sesame oil as the result shows that nonessential toxic heavy metals were below the limit of detection <0.001 mg/kg. The value of copper and iron are 0.0125 mg/kg and 0.1588mg/kg. It guarantees the safe consumption of the sesame waste used as a source of animal feed production without significant health on the consumer. All the toxic heavy metals in the sesame seed fall within the permissible limit of CODEX standard (Codex Alimentarius, 2001).

Conclusion

Sesame waste is also known as sesame meal or sesame oil cake is a by-product of sesame oil extraction from sesame seeds. The sesame waste is made up of wet sesame sludge which is freshly extracted, high moisture content and dry sesame sludge is dried to reduce moisture content. Sesame waste is a by-product of sesame oil extraction, which provides exceptional potential for value-added applications. The sesame waste is rich in nutritional profile, comprising of protein, fiber and minerals which make it a well-suitable resource for animal feed, organic fertilizers, composting, biodiesel and sustainable agriculture practices. From the study, it is shown that the sesame waste is a good source of animal feed and edible oil. Sesame waste helps to reduce waste disposal issues, as potential supplement for animal feed and organic fertilizers. Sesame waste utilization contributes to environmental conservation and economic growth through cost effectiveness solutions.

The parameter (purity, moisture content, refractive index, density, specific gravity, viscosity of the oil, acid value, saponification

value, iodine value, peroxide value, unsaponifiable matter, oil content, free fatty acid and carbohydrates) analyzed in the sesame seeds used for edible oil are in compliance with the regulatory standard NIS 580:2013 Specifications.

The results showed that sesame waste is rich in essential micro nutrients which are required for animal feed production. The concentrations of all essential metals which include calcium, potassium, phosphorus, magnesium, sodium and iron in sesame waste were found to be lower than the permissible limit recommended by regulatory enforcement agency FAO, NESREA except for the concentration of the aflatoxin of the sesame sludge which is above the permissible limit 10 ppb as recommended by FAO. The high aflatoxin value in the sesame sludge sample might be as a result of climate conditions, crop variety, soil quality i.e poor soil fertility, pH and moisture level increase susceptibility. Inadequate waste handling storage of sesame waste, excessive use of pesticide and fertilizer application. The result obtained from the sesame sludge sample analyzed through the various parameters (Nitrogen, Protein, Ash, Crude fibre, Carbohydrate, Residual fat, Moisture, oil, fatty acid) shows the conformance with environmental regulation standard as recommended by NESREA.

References

- Abbas, S. Sharif, M.Kamran, S. Muhammad, F. Tadesse, S. Muhammad T. and Anwar, M. J. (2022) Nutritional and Therapeutic Potential of Sesame Seeds, *Journal of Food Quality*, 6163753, <https://doi.org/10.1155/2022/6163753>

- Aremu, M. O. Olanisakin A., Bako D. A. and Madu P. C. (2006). Compositional Studies and Physiochemical Characteristics of Cashew Nut (*Anacardium Occidentale*) Flour. *Pak. J. Nutr.* 5 (4): 328-333.
- Bach, K.E. Hedemann, M.S. and Laerke, H.N. (2012). The role of carbohydrates in intestinal health of pigs. *Animal Feed Science and Technology* 173(1-2): 41-53.
- Bedigian D. Siegler D. S. and Harlan J.R. (1985). Sesamin, Sesamol and the origin of Sesame. *BioChem. Syst. Ecol.*, 13(2):133-139.
- Codex Alimentarius, (2001). Vegetable Oils 8, Codex Standard 210.
- Dai, S.Y. Jones, B. Lee, K-M. Li, W. Post, L and Herrman, T.J. (2016) Heavy metal contamination of animal feed in Texas. *Journal of Regulatory Science* 01, 21-32
- De Lange C.F.M., Pluske J. Gong J. and Nyachoti C.M. (2010). Strategic use of feed ingredients and feed additives to stimulate gut health and development in young pigs. *Livestock Science* 134(1-3): 124-134.
- De Leeuw, J.A. Bolhuis, J.E. and Bosch G. W.J.J. (2008). Effects of dietary fiber on behavior and satiety in pigs. *Proceedings of the Nutrition Society* 67(4): 334-342.
- Fagbemi T. N. and Oshodi, A. A. (1991). Chemical Composition and Functional Properties of Full Fat Fluted Pumpkin Seed Flour. *Nig. Food. J.*; 9:26-32.
- Gebrekidan, A. and Desta, A. A. (2019). Assessment on The Levels of Selected Essential and Non-Essential Metals in Sesame Seeds (*Sesamum Indicum L.*) Collected from Sheraro Town, Northwest Tigray, Ethiopia. *Bulletin of the Chemical Society of Ethiopia*, 33(2), 191-202.
- Hu, J. and Zhou, L. (2019). Assessment of Microelements in Six Varieties of Sesame Seeds Using Icp-MS. In Iop Conference Series: *Earth and Environmental Science* 330(4), 042063.
- Kheirati R. S., Akrami M. F., Moshtaghi B. H., Pourramezani, F., Jambarsang, S., Kiani, H. and Khalili S. E. (2021). The Chemical Composition and Heavy Metal Content of Sesame Oil Produced by Different Methods: A Risk Assessment Study. *Food Science and Nutrition*, 9(6), 2886-2893.
- Njoku O. U. Boniface J. A. E. Obitte N. C. Odimegwu D. C., and Ogbu H. I. (2010). Some Nutraceutical Potential of Beniseed Oil. *International Journal of Applied Research in Natural Products* 2(4),. 11-19.
- Oswailer, G. D. Carson, T.L. Buck. W. B. and Van Gelder, G.A. (2013). Clinical and Diagnostic veterinary toxicology. Wiley-Blackwell. In Clinical and diagnostic veterinary toxicology. 1985, xiv + 494pp
- Teferi, A. Getachew, A. and Habtremariam, K (2013) Utilization and nutritive value of sesame (*Sesamum indicum L.*) straw as feed for livestock in the Northwestern lowlands of Ethiopia. *Livestock Research for Rural Development* 25:7.
- Vogt, A. C. S. Arsiwala, T. Mohsen, M. Vogel, M. Manolova, V. and Bachmann, M. F. (2021). On Iron Metabolism and Its Regulation. *International Journal of Molecular Sciences*, 22(9), 4591.
- Wei, P. Zhao, F. Wang, Z. Wang, Q. Chai, X. Hou, G. and Meng, Q. (2022). Sesame (*Sesamum indicum L.*): A comprehensive Review of Nutritional Value. Phytochemical Composition, *Health. Nutrient* 14(19):4079. doi: 10.3390/nu14194079.
- Wenk, C. (2001). The role of dietary fiber in the digestive physiology of the pig. *Animal Feed Science Technology* 90(1-2): 21-33.
- Xiang, G. Wen, S. Jiang, X. Liu, X. and He, L. (2011). Determination of Trace Copper (Ii) In Food Samples by Flame Atomic Absorption Spectrometry after Cloud Point Extraction. *Iranian Journal of Chemistry and Chemical Engineering*, 30(3) - Serial Number 59 101-107.
- Yeasmin, S. Chowdhury, T.A. Rana, G.M.M. Rahman, M.M. and Ferdousi, L. (2021). Characteristics of Sesame (*Sesamum indicum L.*) seed meal grown in the northern region of Bangladesh. *Biology, Agriculture and Healthcare*, 11(8).