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# Using Inductively Coupled Plasma Spectroscopy to Detect Heavy Metals Contents in Some Sudanese Vegetable Oils

**Nedal Abdelazim[1], Abdelmoneim Awadelgied[2], Sohad Saad Elwakeel[3], Ahmed Abubaker Mohamed[4]**

[1,3]Sudan University of Science and Technology, Khartoum, Sudan
[2,4]Faculty of Engineering, Karary University, Khartoum, Sudan

## ABSTRACT

One of the most important food industries in every country is vegetable oils production, some of these oils contain natural compounds, which are classified as high purity oils, and others contain harmful components which are classified as law purity oils because they contain heavy metals components and chemical additives. In this paper analysis and characterization of edible oils are perform by Inductively Coupled plasma spectroscopy, the study includes three types of oils (Naama, shams, and afia.) They were sourced from local Sudanese markets. The results showed that the spectra of oil samples are similar, but they show some differences in the concentration of some elements, and the findings indicated that they have toxic heavy metals (Pb, Cu, Hg ,Sr) which are harmful to health that may can cause cancer diseases, and great harms health.

***KEYWORDS:*** *Heavy metals, Sudanese vegetable oils, Concentration (ppm), Inductively Coupled Plasma-ms:*

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## INTRODUCTION

In food vegetable oils are widely used (edible oils), cosmetic, pharmaceutical and chemical Industries. Regarding the world-wide food production, the edible oils derived from various plants and seeds, have an important role in human nutrition due to cholesterol reducing property [1, 2]. The determination of several trace metals, help to evaluate the quality of the edible oils, regarding their freshness and toxicity, this being one of the most important criteria for the quality assessment of the oils from the health point of view [3-4]. In human life Metals play important negative and positive roles [5]. Vegetable oils and fats have small amounts of different metals influenced by several factors, including the species, soil for growth, irrigation water, type, maturity stage, and pollution [6, 5].

Quality of the food products and food safety reduces by heavy metals in the soil and contaminants, and they also poses great risk to the health of animals and humans since heavy metals could be transferred into the chain food (soil-plant human or soil-plant-animal-human)[7]. Oil oxidation have been reported to increase by elements such as copper, zinc, magnesium, and iron, while copper and iron catalyze the decomposition of hydroperoxides, thereby leading to the formation of hazardous substances in oils [8]. Lead, arsenic, mercury, and cadmium are toxic heavy metals found in oils [9]. Heavy metals leading adverse effects on the nutritional value, toxicity, and oxidative stability of oils. Therefore, it is critical to determine the concentrations of heavy metals in various oils [10].

Inductively Coupled Plasma Mass Spectrometry (ICP-MS) is a highly sensitive technique that measures trace and ultra-trace elements by ionizing samples in an argon plasma and detecting the ions by mass [11]. In principle, an ICP-MS instrument comprises a sample introduction system, an

inductively coupled plasma source, a mass spectrometer and an ion detector. Samples are typically prepared as a liquid solution before they are injected into the plasma as aerosol droplets. In the plasma, the sample is successively vaporized, atomized and ionized, and the resulting ions are directed through the mass spectrometer to the detector. The mass spectrometer separates the ions based on their mass-to-charge ratio, and typically is a quadrupole mass analyzer for routine applications. It is important to note that the sample introduction system and plasma are operated at atmospheric pressure, whereas mass spectrometer and ion detection system are operated in a vacuum chamber [12].

Almost all naturally occurring elements and their isotopes can be measured at concentrations from high parts per million down to below single part per trillion levels using an ICP-MS. The exceptions are Ar, N, and O because they are present at high levels from the plasma and air, F and Ne which can't be ionized in an argon plasma, and H and He as they are below the mass range of the mass spectrometer. The extremely low detection limits for much of the periodic table, coupled with a large analytical working range covering up to 10 orders of magnitude are key strengths of ICP-MS, distinguishing it from other analytical techniques and explain why so many industries now rely on ICP-MS [13].

**The basic components of an ICP-MS are**:

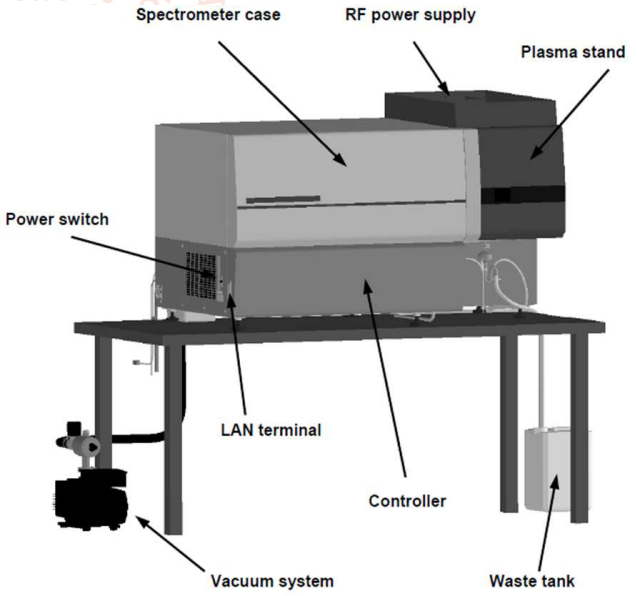
- Sample introduction system – consists of a nebulizer and a spray chamber that inject fine aerosol droplets of the liquid sample into the plasma.
- Inductively coupled plasma – generated by a radio frequency coil, the plasma ionizes the sample aerosol.
- Interface – extracts the ions from the plasma which operates at atmospheric pressure and transfers them into the high vacuum mass spectrometer.
- Ion optics – a train of electrostatic lenses focusing and guiding the ion beam into the mass filtering device while separating it from neutral species and photons.
- Collision/reaction cell – removes interferences from analytic ions.
- Mass analyzer – filters ions by mass-to-charge ratio.
- Detector – counts the ions exiting the mass analyzer
- Instrument control and data processing– managed via the analysis software on the workstation computer [13] [14].

The nearly all-important belongings commit to memory on the subject of the argon ICP plasma is:

1. The argon discharge, with a temperature of around 6000-10000° K, is a tremendous ion source.
2. The ions produced by the ICP discharge are characteristically positive ions, M+ or $M^{+2}$, consequently elements that have a preference to form negative ions, such as Cl, I, F, etc., are extremely thorny to conclude via ICP-MS.
3. The recognition capabilities of the technique can vary with the sample introduction technique used, as different techniques will allow differing amounts of samples to reach the ICP plasma.
4. Recognition capabilities will vary with the sample matrix, which may affect the degree of ionization that will occur in the plasma or allow the formation of species that may interfere with the analytic determination [13][14][15].

**Experimental Samples:**

Three types of Sudanese edible oils (Naama, Shams and afia.). This edible oils produced from (corn oil, peanut, and sunflower oils) were selected as the experimental samples. The oil samples used in this work were purchased as commercial products from a local supermarket in Khartoum, Sudan.




The concentrated nitric acid ($HNO_3$) was pure, specific for trace analysis, and was diluted to 10 % (v/v) concentration with deionized water. All containers, including test tubes with stoppers, were in polypropylene and were cleaned with 5% (v/v) hydrochloric acid and the deionized water. The blank

consisted of the 10% dilute nitric acid and deionized water. Preparation of standards.

The first standard stock solutions had a 1.0 mg/L concentration of each metal and these were used for the preparation of aqueous standard solutions after appropriate dilution with 10 % nitric acid. The concentration ranges of the working solutions were0.001- 0.1 ppm for all metals.

The procedure of the spiked standard preparation was the following:

1 ml of 10% nitric acid containing different concentrations of metal (10-50 ppb) was added to 1g of oil samples.

Statistical analysis

Results of heavy metal contents are presented as the mean. Study data were archived in Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA)

**Results and Discussion:**

The results of the ICp detect some heavy metals in the oils samples tables bellow illustrate this results.

**Table 1. Analysis of Naama oil by using ICP spectroscopy.**

| Measured λ (nm) | Intensity (a.u ) | Elements | Reference | ICP concentration(ppm) |
|---|---|---|---|---|
| 488.132 | 131 | Li II | 59MH | 0.07 |
| 511.319 | 132 | Ti I | 91F | 0.33 |
| 514.949 | 136 | Hg II | SR01 | 1.2 |
| 520.144 | 132 | Pb I | WA68 | 1.9 |
| 534.548 | 132 | Nb I | 75SCM | 2.9 |
| 652.766 | 135 | Ba I | KL99 | 0.61 |
| 664.139 | 131 | Cu II | R69 | 17 |
| 672.484 | 131 | CsII | 81S | 360 |
| 677.507 | 132 | Rb II | R75 | 460 |
| 709.231 | 137 | Zr II | 90JDBA | 0.22 |
| 718.289 | 133 | In II | BC38 | 4.7 |
| 730.949 | 132 | Sr I | 75SCM | 3.4 |
| 757.891 | 135 | S II | KM93 | 280 |
| 764.189 | 131 | Kr II | 33MHD | 0.00 |
| 1048.778 | 134 | K I | 56R | 5.4 |

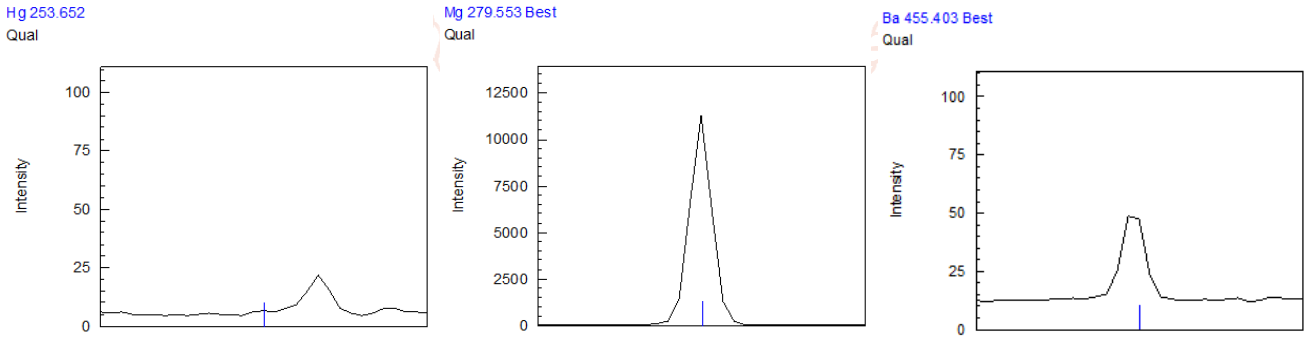



**Fig1: ICP emission spectrum of Naama oil.**

**Table 2. Analysis of ICP Emission Spectrum of Shams oil,**

| Measured λ (nm) | Intensity (a.u ) | Elements | Reference | ICP concentration(ppm) |
|---|---|---|---|---|
| **426.339** | 132 | I iT | 91F | **0.40** |
| **438.646** | 131 | **Pb II** | **WRSH74** | **17** |
| 449.756 | 131 | **NaI** | 56R | **320** |
| .452**847** | 132 | **Ce II** | **C73** | **4.6** |
| 488.132 | 140 | **LiI** | 59MH | **0.09** |
| **542.525** | 131 | **Hg II** | **SR01** | **2.8** |
| .652**766** | 135 | **Ba II** | **KL99** | **0.64** |
| 687.702 | 132 | **SrI** | 72SCM | **6.4** |
| 696.012 | 131 | **PaII** | 926WB | **-** |
| 706.012 | 134 | **ZrI** | 98J | **0.22** |
| 719.240 | 131 | **Rb I** | **B59** | **660** |

| | | | | |
|---|---|---|---|---|
| **740.817** | 132 | **N I** | 75M | **-** |
| 1048.778 | 132 | **KI** | 56R | **7.00** |
| 1055.388 | 131 | **UI** | 926WB | **7.8** |

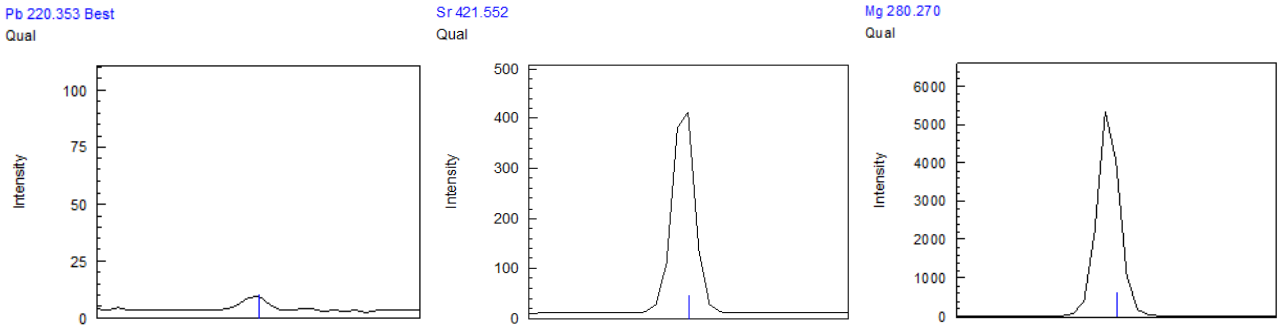



**Fig2: ICP emission spectrum of Shams oil.**

**Table 3. Analysis of ICP Emission Spectrum of Afia oil.**

| Measured λ (nm) | Intensity (a.u) | Elements | Reference | ICP concentration(ppm) |
|---|---|---|---|---|
| 384.**33** | 131 | **V I** | 78AD | **0.05** |
| 386.492 | 133 | **VI** | 78AD | **0.05** |
| 481.**188** | 130 | **Sr I** | **MCS71** | **5.7** |
| **567.711** | 130 | **Hg II** | **SR01** | **4.4** |
| 566.274 | 133 | **TiII** | 91F | **0.33** |
| **677.507** | 130 | **Rb II** | **R75** | **450** |
| 696.012 | 130 | **PaII** | 926WB | **-** |
| 697.**330** | 132 | **Cs I** | **K62b** | **350** |
| 751.722 | 131 | **ArI** | 73N | **-** |
| **755.897** | 131 | **Pb II** | **S75** | **4.5** |
| 807.432 | 130 | **ZrI** | 98J | **0.21** |
| 849.**583** | 130 | **Ce I** | **BWCC91** | **2.8** |
| **890.219** | 130 | **K I** | 63T | **5.7** |
| 997.786 | 131 | **InI** | 67LJ | **7.5** |
| 1000.622 | 132 | **AsI** | 85AH | **10.00** |
| 1003.832 | 133 | **SrII** | 389S | **5.7** |

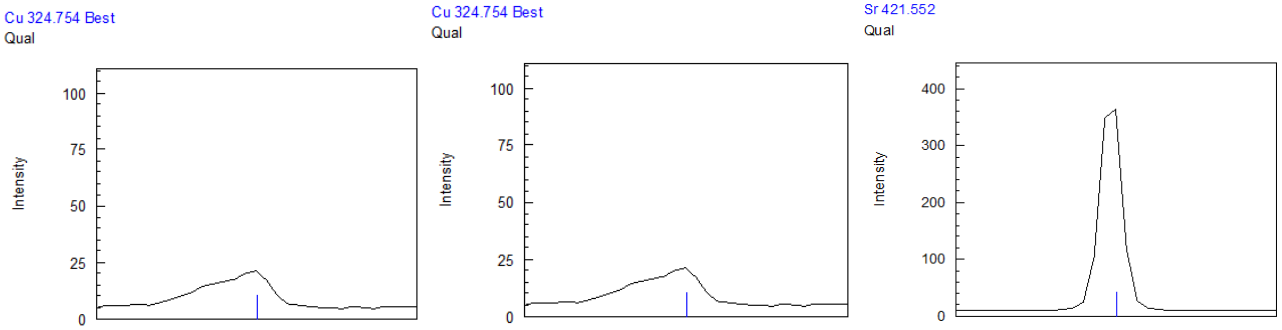



**Fig3: ICP emission spectrum of Afia oil.**

**Discussions:**

From tables results four heavy elements (Cu, Pb, Sr and Hg) were discovered in edible vegetable oil samples by using ICP as shown in table1, 2, 3 and Fig.1, 2, 3.

Copper (Cu) concentrations present in table {1} 17mg/kg the concentration was high than that reported in similar data (0.05mg/kg [15] 0.1mg/kg (Codex2011)

Lead (Pb) concentrations present in table {1, 2, 3} 1.9 mg/kg 17mg/kg, 4.5mg/kg, respectively the concentration was high than that reported in similar data 0.02mg/kg [16] 0.1mg/kg) [17] FAO/WHO 0.1 mg/kg (Codex S 2011). The recommended limit by the EU and National Iranian Standards Organization (0.1 mg/kg).

Strontium (Sr) concentrations present in table {1, 2, 3} 3.4mg/kg, 6.4mg/kg, 5.7mg/kg respectively the

concentration was high than that reported in similar data (0.1mg/kg) [16]

Mercury (Hg) concentrations present in table {1, 2, 3} 1.2 mg/kg, 2.8mg/kg, 4.4mg/kg respectively the concentration was high than that reported in similar data 0.003mg/kg [16].

**Conclusion:**

The ICP-MS analysis revealed the presence of potentially hazardous heavy metals, including Cu, Pb, Sr, and Hg, in all investigated edible oil samples. The detected concentrations exceeded several internationally recommended limits, indicating possible contamination during cultivation, processing, or storage. These findings highlight the necessity of routine monitoring of edible oils to ensure food safety and public health protection. Furthermore, ICP-MS proved to be an effective and highly sensitive analytical technique for the determination of trace and toxic elements in vegetable oils.

**Recommendations:**

From the results, the followings can be suggested as future work:

Inductively coupled plasma spectroscopy, should be focused to improve the ICP system for analysis and examination of crude oil grains before the manufacturing process to determine if there are toxic elements (Cu, Pb, Sr and Hg) to avoid the manufacturing process.

ICP method can be considered in the future as an analytical technique of many classes of all types of oil compounds.

Study the percentage of the heavy elements in oils.

Study the effect of the chemical additives on the toxicity of the oils

Expand the analysis to include additional toxic elements such as Cd, As, Cr, Ni, and Al, together with organic contaminants.

Compare locally produced oils with imported commercial oils to determine differences in contamination levels and quality standards.

Investigate the influence of agricultural practices, fertilizers, pesticides, and environmental pollution on heavy metal accumulation in oil-producing crops.

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