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Identification Of Elements From Indonesian Ginseng Using Nd:YAG Laser-Induced Breakdown Spectroscopy

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Abstract— Ginseng herbal medications provide essential macro, micro, and trace elements that promote the overall well-being of the human body. The analysis of constituents in herbal medicines is crucial. The objective of this study is to determine the elemental composition of ginseng-based herbal medicine using laser induced breakdown spectroscopy (LIBS) and compare it with the X-Ray Fluorescence (XRF) method. Additionally, the study also investigates the impact of environmental air pressure on the emission spectrum obtained. The investigation included employing a Nd: YAG laser beam with a wavelength of 1064 nm. Experimentally, the laser beam was concentrated onto the target sample's surface using a quartz lens with a focal point of 10 cm, resulting in the generation of plasma. The plasma emission was then collected by an optical fiber, thereafter examined using an optical multichannel analyzer (OMA), and transferred to a computer for data analysis using Spectra Lab Software. Following the identification process using the LIBS approach, the results were then compared using the XRF method. The XRF result findings indicated the presence of many macro elements (K, Ca, Na, Mg), micro elements (Ni, Fe, Mn), and trace elements (Al and Ti). The LIBS approach outperforms the XRF method in identifying elements in ginseng-based herbal medicine.

Keywords— Laser induced breakdown spectroscopy; Nd:YAG Laser; Herbal Medicine; ginseng; LIBS.

I. INTRODUCTION

Indonesians utilize herbal medicine, also known as traditional medicine, as an alternative form of treatment. Presently, there is a wide range of developments in the field of herbal medicine, encompassing phytopharmaceuticals, standardized herbal medicines (OHT), and herbal medicines. Herbal remedies are formulated using organic substances, including stem bark, leaves, fruit, and plant roots (rhizomes). Then, either industrially or directly (without an industrial process), this natural substance is processed. Herbal medicine is utilized to increase the body's immunity, alleviate disease symptoms, and halt disease progression[1]. Ginseng-based herbal medicine is one of the medicinal remedies derived from the ginseng plant that the general public uses to treat illness. The human body benefits from the macro-element and micro-element content of the herbal medication ginseng[2]. Several elements, including sodium (Na), calcium (Ca), potassium (K), magnesium (Mg), iron (Fe), and zinc (Zn), are present in herbal medicines[3]. At present, nevertheless, a considerable number of herbal remedies available for purchase in local markets lack proper licensing certification from the Food and Drug Supervisory Agency. Therefore, the identification of constituents in herbal medicines is critical.

Herbal remedies have been analyzed using a variety of techniques. Fifteen samples of American ginseng herbal medicine were analyzed using the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) technique to determine the presence of macroelements (Ca, K, Mg, and Na), microelements (Cu, Ni, Fe, Mn, and Zn), and trace elements (Al, Co, Cd, Ti, Rb, and Sr)[2]. The elemental composition of the herbal medicine derived from Indian ginseng has also been determined using the Atomic Absorption Spectroscopy (AAS) technique. Lokhande et al. (2010) described the constituents of ginseng herbal medicine, which include trace elements (Al, Co, Cd, and Cr), microelements (Zn, Fe, Cu, Ni, and Mn), and macroelements (K, Ca, and Na). At low concentrations, these two techniques are capable of identifying macro and micro elements due to their high sensitivity[4]. Although both approaches are intricate, requiring a substantial quantity of samples and an expensive piece of equipment, they are only applicable to liquid samples and necessitate a lengthy preparation period[5].

An alternative approach for element identification in samples that is both more efficient and straightforward to implement is laser plasma spectroscopy, also known as Laser Induced Breakdown Spectroscopy (LIBS). The laser plasma spectroscopy technique possesses the capability to discern a wide range of sample types, including solid, liquid, and gas[6]. In addition to these benefits, the LIBS method is characterized by its high sensitivity, relatively inexpensive hardware, and rapid implementation time, which enables the acquisition of results promptly for subsequent data analysis[7].

The present investigation employed laser plasma spectroscopy (LIBS) to ascertain the elemental composition of ginseng herbal medication. A standard 1064 nm Nd: YAG laser is in use. The obtained elemental content from laser plasma spectroscopy was subsequently compared to that from the XRF method. This research contributes to the knowledge that laser plasma spectroscopy is an efficient, economical, and rapid technique for determining the elemental composition of herbal medicines containing ginseng.

II. MATERIAL AND METHODS

2.1. Experimental Procedure

The sample used in this study was ginseng based-Indonesian herbal medicine overwhelmingly available in the local market. In the procedure, the sample was prepared in the form of pellet by pressing the sample powder using hydraulic press machine.

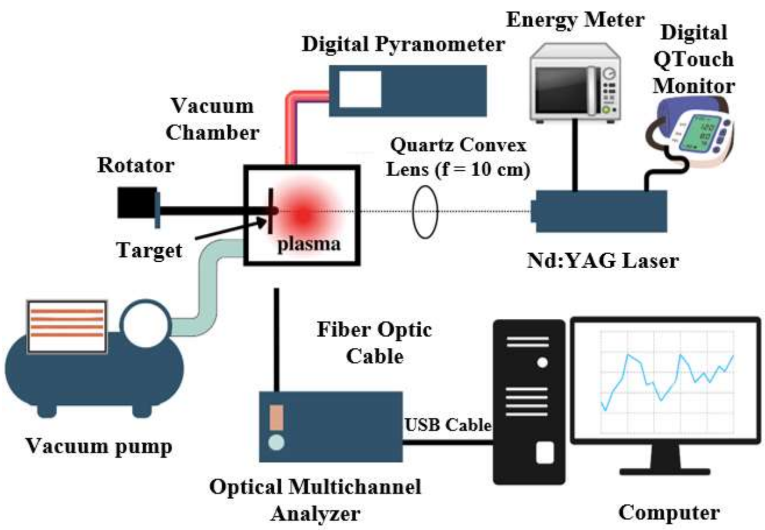
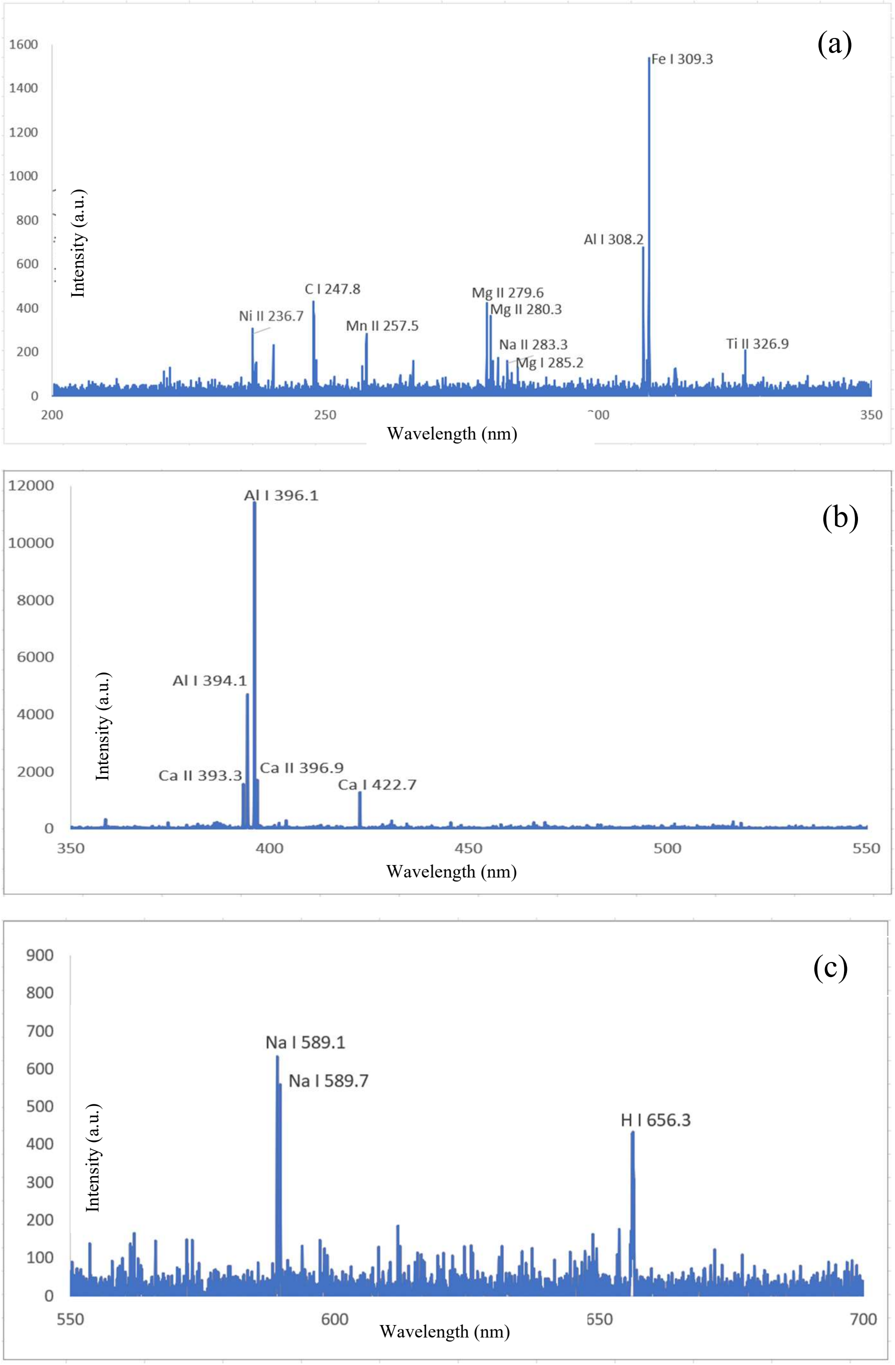


Figure 1. Experimental Setup

Figure 1 shows a schematic of the tools used in this research. The firing of a basic 1064 nm Nd:YAG laser was controlled using software integrated into the computer. The laser beam was directed so that it precisely focused on the sample in the chamber with a quartz lens (focus point 10 cm) placed in front of the chamber to focus the laser so that the beam hits the sample. After the laser fired the sample, a plasma will form which carries optical information on the sample. The light from the plasma is then captured by an optical fiber and then taken to the OMA (Optical Multichannel Analyzer). The optical information and produced spectrum graphs that appear on the computer was then analyzed.

III. RESULT AND DISCUSSION

Figure 2 depicts the element content in ginseng herbal medicine, specifically the element's emission spectrum obtained using LIBS. The spectrum formed has high emission intensity. The element magnesium is formed at several wavelengths, namely Mg II 279.6 nm, Mg II 280.3 nm, and Mg I 285.2 nm. The emission spectrum of the neutral magnesium element (Mg I) at a wavelength of 285.2 nm is obtained from a transition energy of 4.34 eV to the ground state. Meanwhile, the element Mg II has a different level of intensity, the magnesium ion (Mg II) with a wavelength of 280.3 nm has a relative intensity of 366.5, the relative intensity of Mg II 279.6 nm is 401.6 nm. This difference in intensity is due to the probability of each energy transition having a unique wavelength. The high level of intensity depends on the probability of the electron dropping to a lower level which is indicated by the thickness of the line on each line. The thicker the line available, the greater the probability that electrons will move under these conditions. The magnesium is an important mineral that is involved in enzyme reactions in the body. Magnesium also plays a role in reducing risk factors related to heart disease and blood vessel disorders[8].



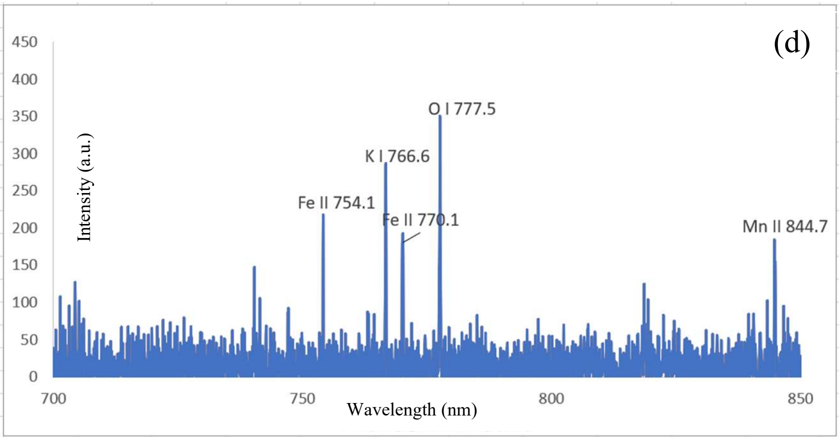


Figure 2. Emission spectra obtained from the ginseng herbal medicine using LIBS at wavelength region of (a) 200-350 nm, (b) 350-550 nm, (c) 550-700 nm, and (d) 700-850 nm

An emission spectrum with a wavelength of 236.7 nm was detected. This emission line is the line of the ionic Ni II element. The highest peak of the emission spectrum formed in Figure 2(a) is the neutral Fe I with a wavelength of 309.3 nm. with an energy transition from 5.61 eV to 1.6 eV. The ionic Fe II emission line is detected at a wavelength of 770.1 with an energy transition from 13.04 eV to 10.19 eV. Ionic Fe (Fe II) is also identified at a wavelength of 754.1 nm. The Na I emission spectrum lines are detected at wavelengths of 589.1 nm and 589.7 nm. The emission spectrum of ionic sodium Na II is also formed at a wavelength of 283.3 nm. The Ti II titanium emission line is formed at a wavelength of 326.9 nm. The element potassium (K I) was identified at a wavelength of 766.6 nm with an energy transition from 1.61 eV to the basic energy.

Figure 2(b) shows two wavelengths with high intensity relative to ionic Ca spectra, at 393.3 nm (1568.8) and 396.9 nm (1719.7). The increased intensity of these two wavelengths is due to their lower energy level transitions when compared to the other Ca spectra. Each energy transfer produces a distinct wavelength. The high level of intensity is determined by the probability of the electron descending to a lower level, as evidenced by the thickness of each line. The thicker the line available, the more likely electrons will travel under these circumstances. When the energy level difference is narrows, the electron transitions become much simpler to carry out because electrons may be de-excited with a minimal amount of energy, resulting in a spectrum. Thus, the intensity of Ca 393.3 nm and 396.9 nm represents a low energy level transition in comparison to other energy transitions, with 3.15 eV for the wavelength of 393.3 nm and 3.12 eV for the wavelength of 396.9 nm. The emission spectra at 422.7 nm is that of the Ca I element, which results from a 2.93 eV energy shift to ground state energy level. This calcium content promotes muscular and bone health[8].

The aluminum element has a reasonably high intensity at the wavelength of Al I 394.1 nm, namely 4708.6, with an energy shift from 3.14 eV to the ground state energy level. Neutral Al I element has a relative intensity of 11366 at 396.1 nm with an energy transition from 3.14 eV to 0.01 eV. The Al I element has a relative intensity of 673.5 at 308.2 nm with an energy transition from 4.02 eV to the ground state energy level. The Mn II spectrum emission line was identified at 257.5 nm, with an energy change from 8.72 eV to 3.9 eV, and at 844.7 nm, with an energy transition from 12.11 eV to 10.64 eV. The body requires this element to ensure proper metabolic function[9]. Even though this element is only required in tiny amounts, its absence will impair the metabolic process.

Ginseng herbal medication contains organic elements such as C, H, and O. These organic components are one of the chemicals that comprise the human body. Emission line was seen at 247.8 nm with a relative intensity of 386.1. This emission line represents the C I element's energy shift from 7.68 eV to 2.68 eV. The H I element has a relative intensity of 424.1 at 656.3 nm, with an energy transition from 12.75 eV to 10.19 eV. The O I element's emission line at 777.5 nm, which transitions from 10.74 eV to 9.14 eV, has a relative intensity of 350.

Several components found in the natural medicine ginseng were discovered using the laser plasma spectroscopy technique, including macro elements (K, Ca, Na, Mg), micro elements (Ni, Fe, Mn), and trace elements (Al and Ti). These elements are trace elements in ginseng herbal medicine, representing the elemental composition. Lokhande (2010) used Atomic Absorption Spectroscopy (AAS) to determine the trace element content of ginseng herbal medicine, and discovered the presence of macro elements (K, Ca, and Na), micro elements (Zn, Cu, Fe, Ni, and Mn), and trace elements (Al, Co, Cd, and Cr)[4]. The X-Ray Florescence (XRF) technique identified elements from Brazilian ginseng herbal medicine, including C, Ca, Mn, Ni, Cl, Ti, Fe, Cu, Br, Rb, Sr, and Zn[10]. Inductively Coupled Plasma Mass Spectrometry (ICP-MS) was used to identify macro elements (Ca, K, Mg, and Na), micro elements (Cu, Ni, Fe, Mn, and Zn), and trace elements (Al, Co, Cd, Ti, Rb, and Sr) in fifteen samples of American ginseng herbal medicine[2].

Several elements identified in this study were discovered using the different approaches utilized in the previous research. To confirm that the laser plasma spectroscopy (LIBS) technique can be utilized to identify the element content in herbal medicines, another technique, X-Ray Fluorescence (XRF), was employed as a control.

Table 1 Elements from ginseng herbal medicine identified by LIBS and XRF.

No	Elements	LIBS	XRF
1	C	✓	-
2	H	✓	-
3	O	✓	-
4	Na	✓	-
5	Si	✓	✓
6	Al	✓	✓
7	Mn	✓	✓
8	Mg	✓	✓
9	Cu	✓	✓
10	K	✓	✓
11	Ca	✓	✓
12	Fe	✓	✓
13	P	-	✓
14	S	-	✓
15	Cl	-	✓
16	Zn	-	✓
17	Rb	-	✓
18	Sr	-	✓
19	Zr	-	✓

Table 1 shows the data from comparative examinations of the elemental composition of ginseng herbal medicine utilizing LIBS and XRF techniques. Elements discovered by the laser plasma spectroscopy/LIBS and XRF techniques in ginseng herbal medicine samples include silicon (Si), aluminum (Al), manganese (Mn), magnesium (Mg), potassium (K), calcium (Ca), iron (Fe), and copper (Cu). The XRF approach cannot identify organic elements such as carbon (C), hydrogen (H), oxygen (O), and sodium (Na) in samples with low atomic numbers[11]. Phosphorus (P), sulfur (S), chlorine (Cl), zinc (Zn), rubidium (Rb), strontium (Sr), and zirconium (Zr) are elements that may be identified using the XRF technique but not by laser plasma spectroscopy or LIBS. This element cannot be identified using the LIBS technique due to the element's high energy transition, which is insufficient to form plasma.

IV. CONCLUSIONS

Identification of nutrient elements from the ginseng herbal remedies using LIBS was successfully conducted. Some elements, including macro elements (K, Ca, Na, Mg), micro elements (Ni, Fe, Mn), and trace elements (Al and Ti) have been identified. The identified elements were compared and confirmed by using the XRF techniques. The results certified that LIBS can clearly identify organic light elements such as C, H, and O, which are difficult to be detected using XRF technique.

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