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Research Article
Characterization of Bioactive Compounds and Nutritional Qualities of *Ipomoea batatas* and *Solanum tuberosum*: Food and Rural Livelihoods

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Abstract
Background and Objective: Rural livelihoods are a kind of rural life where foods are being produced majorly for consumption and devoid of the knowledge of the presence of various bioactive compounds which are essential for physiological functions in the human body. The research was aimed at the characterization of the bioactive compounds of *Ipomoea batatas* and *Solanum tuberosum*. **Materials and Methods:** *Ipomoea batatas* and *Solanum tuberosum* were air-dried and powdered using a grinder (Sumeet CM/L 2128945). Proximate analysis was done according to Methods of Association of Official Analytical Chemists, the mineral analysis was done using atomic absorption spectrophotometer, extraction of oil was done using Soxhlet apparatus. The oil extract was characterized using a gas chromatography-mass spectrophotometer and identified compounds were screened for drug properties using an online Osiris server. **Results:** The proximate results showed that the two samples had the same protein contents (24.70±0.21%) but *Solanum tuberosum* had higher fibre (10.99±0.12%). The metal analysis showed the calcium content to be higher in *Solanum tuberosum* (10.68 mg/100 g) and potassium content was higher in *Ipomoea batatas* (51.80 mg/100 g). Identified compounds in the oil extract such as Oxazoline exhibited various drug properties such as drug-likeness and toxicology. **Conclusion:** The research had shown these two plants are nutritionally rich and possess bioactive compounds that are good sources of chemotherapeutic agents.

Key words: Proximate analysis, metal contents, bioactive compounds, drug-likeness, toxicology

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Ipomoea batatas L. species are locally consumed food crops in Ado Ekiti, Nigeria without the awareness of the major health benefits associated with the consumption. *Lam* belongs to the group of Convolvulaceae[1] and they are tuber crops that rank among the seventh and fifth in production in the world and Africa[2]. They are locally cultivated in Nigeria and has many nutritional benefits[3]. Among the previous research work carried out on a variety of *Ipomoea batatas* (L.) Lam had shown to contain phytochemicals that are of importance to human health[4,5]. Konczak *et al.*[6] had reported the functions of phytochemicals to include antimutagenic, anti-inflammatory, antimicrobial and anti-carcinogenesis. Moreover, the tuber crops contain no saturated fatty acid such as oxalic acid[4]. Further research on *Ipomoea batatas* species had shown the presence of mineral elements such as calcium, iron and high vitamin C and E contents[4]. In addition, Chengcheng *et al.*[7] had shown the presence of Hyperoside, 3,4,5-Tricaffeoylquinic acid, 3-Caffeoylquinic acid and 3,5-Dicaffeoylquinic acid in *Lam* species using High-Performance Liquid Chromatograph Mass Spectrophotometer. In addition, Ayeleso *et al.*[8] had shown that the Lam species investigated were all rich in mineral elements such as calcium, iron, sodium and magnesium and also rich in total fibre and protein. Traditionally, the plant has always being used for the treatment of oral infections, inflammatory diseases and in the management of diabetes[9]. Furthermore, Vanessa *et al.*[10] had shown that the *Lam* species had high protein, crude fibre and total carbohydrate contents. Also, Mohammad *et al.*[11] had reported the high protein, crude fibre and total fat contents of nine varieties of *Lam* species investigated. Recently, scientists at the Institute for Food Research have discovered that *Ipomoea batatas* (L.) Lam contains chemicals called kukoamines, which are associated with lowering blood pressure[12]. Furthermore, the energy role played by *I. batatas* can't be overemphasize[13] and Pochapski *et al.*[14] had reported the medicinal importance of the plant in the treatment of inflammatory and/or infectious oral diseases in Brazil. Also, Ludvik *et al.*[15] had said that in the regions of Kagawa, Japan, a variety of *Ipomoea batatas* (L.) Lam has been eaten raw to treat anaemia, hypertension and diabetes. Moreover, The Monpa ethnic groups of Arunachal Pradesh, India, use the tubers of sweet potato as a staple food and the leaves as fish feed[16]. The various nutritive qualities of *Ipomoea batatas* L. species widely reported necessitated the current study of the locally produced and consumed species.

The goal of this study was aimed at the investigation of the proximate and mineral analysis of the *Ipomoea batatas* and *Solanum tuberosum* and to characterize the bioactive compounds present in the oil extract to identify the drugs likeness and the toxicities such as mutagenic, tumorigenic, irritability and reproductive effects of the compounds present.

MATERIALS AND METHODS

Study area: The two samples were analyzed in the chemistry laboratory, Afe Babalola University Ado Ekiti, Nigeria between the period of 20th February to 30th April, 2020.

Sample source: Fresh samples of *Ipomoea batatas* and *Solanum tuberosum* were purchased from the king's market in Ado-Ekiti, Ekiti State, Nigeria on the 15th April, 2019.

Sample preparation: The 5 kg of the tubers were washed, hand peeled and trimmed to remove defective parts. Then the tubers were grated into thin chips (5 mm) and dried in an air convection oven at 40°C for 30 hrs. The dried chips were powdered using a laboratory-scale grinder (Sumeet CM/L 2128945) and sifted through a 300 μm sieve to obtain the potato flour. The flour samples were sealed and packed in airtight containers for further analysis.

Extraction of oil: The conventional method of extraction involves the use of the Soxhlet apparatus. One gram of dried sample was wrapped in filter paper, placed in a fat-free thimble and then introduced in the extraction tube. Weighed, cleaned and dried receiving beaker was filled with petroleum ether and fitted into the apparatus. The water and heater are turned on to start extraction. After 6 siphoning, ether was allowed to evaporate and the beaker disconnected before the last siphoning. The extract was transferred into a clean glass dish with ether washing and evaporated on the water bath. The dish was then placed in an oven at 105°C for 2 hrs and cooled in a desiccator.

Mineral composition of flours: Association of Official Analytical Chemists[17] method was employed. The elemental constituents (Ca, Zn, Fe, Mg, K and Na) in the *Ipomoea batatas* and *Solanum tuberosum* were analyzed using atomic absorption spectrophotometer (AAS Buck Scientific Model 210 VGP and Flame Photometer FP 902 PG, England).

Proximate composition of flours: The moisture, crude fibre, crude protein, ash, crude fat and carbohydrate content of the samples were determined using methods of the Association of Official Analytical Chemists[17], without modification.

Characterization of oil: GC-MS analysis of oil extracts of four varieties of yam was performed using TurboMass GC System, fitted with an Elite-5 capillary column (30 m, 0.25 mm inner diameter, 0.25 μm film thickness; maximum temperature, 350°C coupled to a Perkin Elmer Clarus 600C MS. Helium was used as a gas carrier at a constant flow rate of 1.0 mL min^{-1}. The injection, transfer line and ion source temperatures were 280°C. The ionizing energy was 70 eV. The oven temperature was programmed from 70°C (hold for 2 min) to 280°C (hold for 10 min) at a rate of 5°C min^{-1}. The crude extract was solubilized with chloroform and filtered with a syringe filter (Corning, 0.45 μm). Volumes of 1 μL of the extracts were injected with a split ratio of 1:20. The data were obtained by collecting the mass spectra within the scan range 50-550 m/z. The identification of chemical compounds in the extracts was based on retention time; the mass spectra matched those of standards available at the NIST library.

Statistical analysis: The proximate analyses were done in triplicates and ANOVA statistical method was used to determine the mean and Standard Deviation (SD).

RESULTS AND DISCUSSION

The research had shown the novel bioactive compounds with various drug properties and no toxicological effects, the identified compounds showed positive drug-likeness, an indication that they are drugs that have been found to possess various therapeutic actions, such as Oxazolidine, 1,2,4-Triazole, pyrrolidinone and Ascorbic acid had the highest percentage quality. The analysis was significant as a result of the different bioactive compounds identified with no toxicity and the high protein contents found in the two plants.

From the result of Table 1, the crude protein contents of *Ipomoea batatas* and *Solanum tuberosum* were in the same range of 24.60±1.90 and 24.70±0.21%, Moreover, the crude fibre content of *Solanum tuberosum* was higher 10.99±0.12% than that of *Ipomoea batatas* 4.27±1.20%, Also, *Solanum tuberosum* fat content 13.94±2.14% was higher than that of *Ipomoea batatas* 7.21±0.16. The Carbohydrate content of *Ipomoea batatas* 60.34±0.81% was higher than that of *Solanum tuberosum* 50.48±1.79%. However, comparison of results with previous studies, Vanessa *et al.*[10] had shown that the crude protein content of Kabode (*Ipomoea)* (4.50±0.01), Irene (*Ipomoea)* (3.25±0.01), Tib (*Ipomoea)* (4.6±0.40%) were all lower than that of *Ipomoea batatas* (24.60±1.90%) and (24.70±0.21%) *Solanum tuberosum*, respectively, also Mohammad *et al.*[11]

Table 1: Proximate composition of protein and carbohydrate contents

Samples parameters (%)	*Ipomoea batatas*	*Solanum tuberosum*
Moisture content	5.07±0.20	4.53±0.06
Crude protein	24.60±1.90	24.70±0.21
Crude fat	7.21±0.16	13.94±2.14
Ash content	5.59±0.06	8.81±0.17
Crude fibre	4.27±1.20	10.99±0.12
Carbohydrate	60.34±0.81	50.48±1.79

Mean±standard deviation of triplicate determinations, %: Percentage. It is worthy to note that the samples were rich in protein content

had shown that the crude protein content of orange-fleshed *Ipomoea* with peel (BARI SP4 (5.83±0.30a g/100 g) BARI SP (sweet potato) (72.19±0.75e g/100 g) were lower when compared to *Ipomoea batatas* (24.60±1.90%) and *Solanum tuberosum* (24.70±0.21%). The higher crude protein contents of *Ipomoea batatas* and *Solanum tuberosum* are indicating tools that can be used for building and repairing body tissues. The variation in the protein contents could be a result of soil condition, time of planting and a host of others. In another development, when compared to previous studies, Vanessa *et al.*[10] had shown crude fibre content of *Ipomoea* (1.41±0.14%), Bela-Bela *(Ipomoea*) (1.50±0.01%) were all lower than that of *Solanum tuberosum* (10.99±0.12%) and *Ipomoea batatas* *(*4.27±1.20%). In addition, Mohammad *et al.*[11] had shown the crude fibre contents of BARI SP 9 (*Ipomoea*) 0.44±0.16ac g/100 g, BARI SP 1 (*Ipomoea*) 0.40±0.12bcd g/100 g, BARI SP 8 (*Ipomoea*) (0.53±0.13a g/100 g), BARI SP 4 (*Ipomoea*) (0.54±0.14a g/100 g) and they were all lower than that of *Ipomoea batatas* (4.27±1.20%) and *Solanum tuberosum* (8.81±0.17%). The physiological function of crude fibre cannot be overemphasized as it is essential for efficient removal of waste, improve digestion and lowering the risk associated with coronary heart problems[18]. There is strong connectivity between moisture content (dry weight basis) and crude fibre as it essential for the provision of energy by hydrolyzing a phosphate group from adenosine triphosphate[19-20] proffered strong correlation between moisture contents and fibre, which could be of interest to human health as the fibre is easily digested and disintegrated.

From the result of Table 2, *Ipomoea batatas* were richer in potassium content (51.80 mg/100 g) than *Solanum tuberosum* (39.63 mg/100 g). Moreover, the sodium content of *Solanum tuberosum* (7.53 mg/100 g) was higher than that of *Ipomoea batatas* (3.85 mg/100 g), potassium values observed in these *Ipomoea* species were low when compared to the Recommended Daily Allowance (RDA) of potassium (4700 mg). The two plants were lower in iron contents. The sodium-potassium ratio of *Solanum tuberosum* (0.190 mg/100 g) was higher than *Ipomoea batatas*

Table 2: Metal analysis (mg/100 g) of rich potassium contents of the samples analyzed

Samples	Fe	Zn	Mg	Ca	Na	K	Na/K	Ca/Mg
Ipomoea batatas	0.08	0.15	0.61	8.02	3.85	51.80	0.074	13.148
Solanum tuberosum	0.02	0.08	0.59	10.68	7.53	39.63	0.190	18.102

Ca/Mg greater than 1 and Na/K less than 1

Table 3: Identified compounds detected in the oil extract of *Ipomoea batatas*

Peak number	Retention time (min)	Quality (%)	Compound name	Chemical formula	Case no.
1	3.342	0.06	1,2,4-Triazole	$C_2H_2ClN_3$	6818-99-1
5	4.075	1.40	2-Ethyl-2-oxazoline	C_5H_9NO	0431-98-8
6	4.61	0.46	1,2,3-Trimethyldiaziridine	$C_4H_{10}N_2$	113604-56-1
12	8.981	0.27	N-Acetyl oxazolidine	$C_5H_9NO_2$	115615-36-6

2-ethyl-2-oxazoline which had the highest (%) quality and 1, 2, 4-Triazole least (%) quality

Table 4: Drug properties of some of the identified compounds of *Ipomoea batatas* (oxazolidine, triazole, diaziridine) with their drug-likeness and toxicological properties (mutagenic, tumorigenic)

Compound	Drug likeness	Mutagenic	Tumorigenic	Irritability	Reproductive effect
Diaziridine	1.0634	None	None	None	None
Oxazolidine	0.30463	None	None	None	None
2-ethyl -2-oxazoline	0.84743	None	None	None	None
1,2,4-Triazole	1.7653	None	None	High	None

Source: Thomas *et al.*[41]

(0.074 mg/100 g). Also, the Ca/Mg ratio of *Solanum tuberosum* (18.102 mg/100 g) was higher than that of *Ipomoea batatas* (13.148 mg/100 g), however, the value was higher than the reported case by another author[21] Ca/Mg>1.0. The Mg content of *Ipomoea batatas* (0.61 mg/100 g) was higher than that of *Solanum tuberosum* (0.59 mg/100 g). The calcium content of *Solanum tuberosum* (10.68 mg/100 g) was higher than that of *Ipomoea batatas* (8.02 mg/100 g). When compared to previous studies, the magnesium contents were lower than that reported previously (18.30 mg/100 g) and (22.2 mg/100 g) for *Ipomoea batatas* and *Solanum tuberosum*. Also, Ukom *et al.*[22] had shown the Mg content to be (12.2 and 30.4 mg/100 g) for varieties of *Ipomoea* species studied. The calcium content of *Solanum tuberosum* (10.68 mg/100 g) was higher than that of *Ipomoea batatas* (8.02 mg/100 g), however, the results were lower than the *Ipomoea* flour for a variety of *Ipomoea* (45-55 mg/100 g)[23] and lower than that of Kabode (*Ipomoea*) (47.8±0.17[d] mg/100 g)[10]. On the other hand, the current results were lower than the report of 23.8 mg/100 g on *Ipomoea* fries[24]. The RDA value for calcium in an adult male is 1000 mg[25].

However, it is well documented that *Ipomoea* species are a potential remedial crop for many tropical small holder farmers due to its high productivity and low input requirements, while its usefulness for both food and feed (dual purpose) makes it very attractive in resource-poor regions where land availability is decreasing[26]. Moreover, mixed crop-livestock systems have a crucial role to play in the bio-economic improvement of outputs for smallholder farmers and improving methods for sweet potato cultivation could increase their ability to feed their animals and provide nutrition for their households[27].

In another development, Fig. 1 showed the chromatogram of *Ipomoea batatas* having thirty-eight peaks, different retention times (min), compounds identified in the chromatogram include triazole, diaziridine and others. Furthermore, the peaks in the chromatogram showed the total numbers of compounds present in the extract with corresponding percentages of composition. Each peak corresponds to elucidated compound in the extract with percentage composition, retention time and their chemical identities such as molecular formula. It is worthy to mention that thirty-eight peaks correspond to thirty-eight compounds present in the extract, however, four compounds were identified with their drug properties as shown in Table 3 and 4.

From the result of Table 3, 2-Ethyl-2- Oxazoline has the highest percentage quality 1.40%, identified at peak 5, retention time 4.075 min and 1,2,4-Triazole with percentage quality 0.06%, retention time 3.342 min and identified at peak 1 was the least.

Table 4 showed the drug properties of the identified compounds and their toxicological effects, compounds such as diaziridine, oxazolidine, melamine and triazole all had positive drug-likeness and no toxicological effects except melamine having high mutagenic, tumorigenic and irritability effects. The positive drug-likeness of identified compounds was an indication that they were drugs available for the

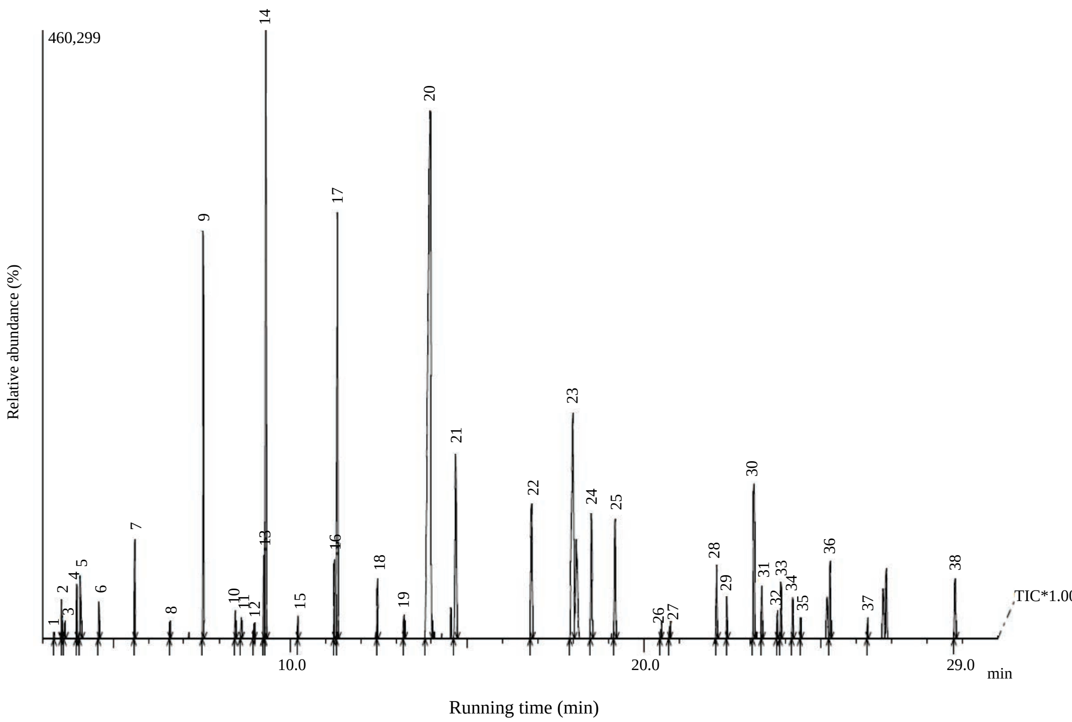

Fig. 1: Chromatogram of *Ipomoea batatas*

Table 5: Identified compounds detected in the oil extract of *Solanum tuberosum* (pyrrolidinone, pyrazole, oxazolidine)

Peak number	Retention time (min)	Quality (%)	Compound name	Compound formula	CAS no.
5	4.059	0.50	2-Pyrrolidinone	C_5H_9NO	872-50-4
6	4.594	0.11	1,2,3-Trimethyldiaziridine	$C_4H_{10}N_2$	113604-56-1
13	7.125	0.11	Pyrazole-4-carboxaldehyde, 1-ethyl-5-methyl-	$C_7H_{10}N_2O$	0-00-0
30	14.308	32.44	l-(+)-Ascorbic acid 2,6-dihexadecanoate	$C_{38}H_{68}O_8$	28474-90-0
24	11.608	0.06	1,2-Oxazolidine	C_3H_7NO	504-72-3

Table 6: Drug properties of some of the identified compounds in the oil extract *of Solanum tuberosum* (pyrazole, diaziridine, pyrrolidone, oxazolidine and ascorbic acid with no toxicological effects)

Compound name	Drug likeness	Mutagenic	Tumorigenic	Irritability	Reproductive effect
3,3-Diethyl-2-pyrrolidinone	4.6125	None	None	None	None
Diaziridine	1.0634	None	None	None	None
Pyrazole	2.3434	None	None	None	High
Ascorbic acid	0.023806	None	None	None	None
Oxazolidine	0.30463	None	None	None	None

Source: Thomas *et al.*[41]

treatment of various ailments and they possess no toxicity on human health. Triazole, oxazolidine and diaziridine derivatives have been well investigated for various therapeutic activities.

Figure 2 showed the chromatogram of *Solanum tuberosum* having 61 peaks and different retention times. Moreover, the total peaks in the chromatogram showed the total number of compounds present in the extract as revealed by the use of Gas-Chromatography Mass-Spectrophotometer. Each peak corresponds to a compound with its associated chemical identities such as retention time and percentage quality. However, only five compounds were identified as shown in Table 5 with their corresponding identities such as percentage quality and molecular formula for the study as a result of their drug properties.

From the result of Table 5, it is pertinent to note that Ascorbic acid had the highest percentage quality 32.44% while oxazolidine had the lowest 0.06%.

In Table 6, the identified compounds in the chromatogram of *Solanum tuberosum* showed positive drug-likeness and no toxicological effects such as pyrazole of drug-likeness (2.3434), oxazolidine (0.30463). Furthermore,

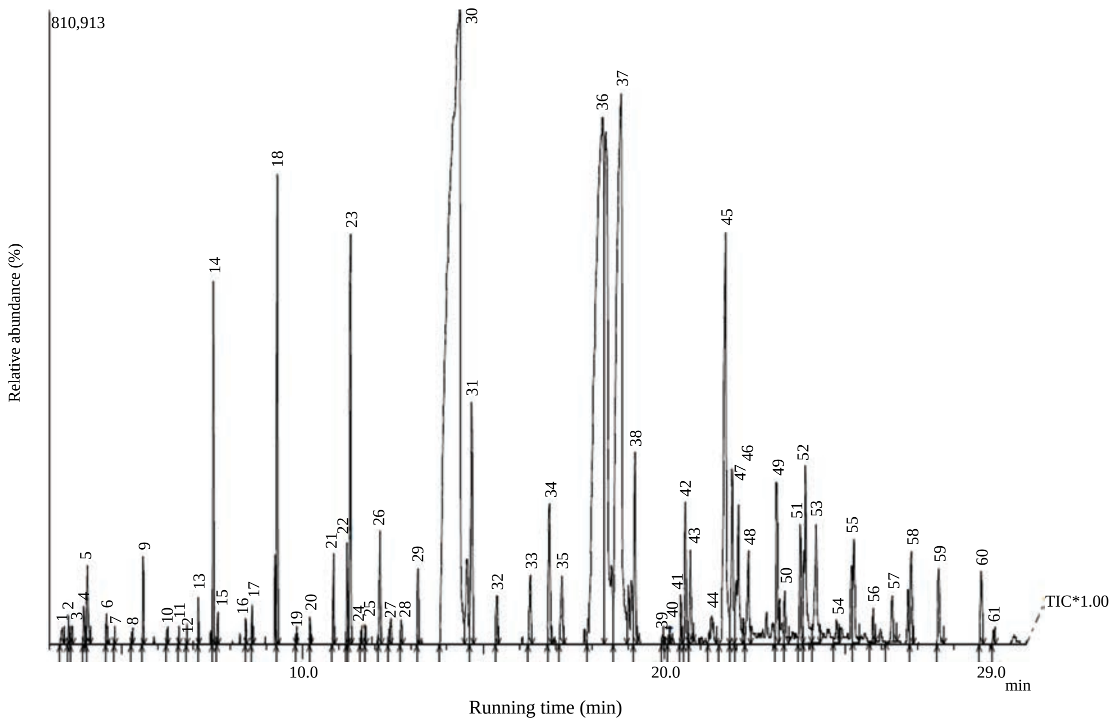

Fig. 2: Chromatogram of *Solanum tuberosum*

various drug properties of identified compounds have been well researched into and these include phosphorus derivatives containing two or three phosphorus- N-aziridine bonds, which are effective alkylating anticancer agents[28], Moreover, oxazolidinones are a new class of antimicrobial agents against gram-positive pathogenic bacteria[29], furthermore, another author[30] had shown that Oxazolidinones represent a new class of synthetic antibacterial agents active against multiple-resistant gram-positive pathogens, including Methicillin-resistant *Staphylococcus aureus* (MRSA), penicillin-resistant streptococci and vancomycin-resistant enterococci. In another development, the various chemotherapeutical values of triazole derivatives have been enumerated[31-32], moreover, It follows from the literature that the triazole derivatives possess a wide range of pharmacological activities such as antimicrobial[33-34] analgesic[35], anti-inflammatory, local anaesthetic[34], anticonvulsant[36], antineoplastic[37], antimalarial[38], antiviral[39], antiproliferative[40] and anticancer activities[40]. Many triazole-based derivatives are available as medicines[40]. Moreover, the present research shows more light on the drug-likeness and various toxicological properties of the bioactive compounds present in the oil extract and it will be an indication tool for scientists to beam their searchlight for the discovery of novel drug candidates from the plants.

CONCLUSION

The research work has revealed the richness of crude protein contents and bioactive compounds present in the oil extract of the examined plants and it can be established that the plants are a good source of therapeutic agents.

SIGNIFICANCE STATEMENT

This study discovered various drug candidates with numerous chemotherapeutic potentials which could be beneficial to the human being. This study will help the researchers to uncover novel bioactive compounds by subjecting the plants to further isolation and characterization with aim of discovering novel drug candidates Thus, a new theory on drug candidates using food crops may be arrived at.

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