Journal of Tropical Agriculture 62(1): 81-96, 2024

Phytochemical screening and potential effects of *Farsetia aegyptia* turra seeds: A native desert herb, from Kuwait

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Received on 12 February 2024; received in revised form 12 March 2024, accepted 06 April 2024.

Abstract:
Native flora and their seeds are widely used in traditional medicine to treat a wide range of illnesses. Kuwait is an arid region with extensive desert ecosystems richly covered with indigenous vegetation, having wide range of therapeutic benefits. The study is intended to explore the phytochemicals in the seeds of a native desert plant, *Farsetia aegyptia*, to relate with their pharmacological features using GC-MS. The chromatogram portrayed the presence of 21 phytochemicals, the highest being Â-D-Glucopyranose, 1, 6-Anhydro- (26.48%) contributing as a natural energy source, with antitumor and antioxidative properties. The cyclohexanone oxime and Furancarboxaldehyde, 5- (Hydroxymethyl were perceived in 21.22 % and 20.96 % with wide potential to inhibit microbial infections, with potential cytotoxic effects as they possessed antioxidant properties.Other notable phytochemicals detected in prominent quantities are Pentanenitrile, 5-(Methylthio) - and Cis-Vaccenic acid in 11.79 and 5.64%, with potent anticancer, antimicrobial and antioxidative activities. Many other fatty acids, as well as their esters, amides, amines, quinones, sterols, vitamins, and other compounds, have been found to have a variety of benefits, that can alleviate severe human ailments. The study opens the door to develop novel herbal medications with an ignored native plant flora, which have the potential to treat fatal sicknesses, but still require more clinical evaluations to fully comprehend their effects. Further research is necessary to evaluate these results for possible clinical applications.

Keywords: *Farsetia aegyptia*, GC-MS, Kuwait, Medicinal desert plants, Methanolic seed extracts, Phytochemicals, Therapeutic effects

Introduction

Native flora is unique, as it preserves life on earth and represents a country's legacy. It offers sustainable aid to the community by contributing low-cost nourishes for grazing livestock, a source of valuable gene pool for research, and for the development of effective natural medications to meet primary healthcare needs in several countries. The medicinal properties of native vegetation have been explored and in demand, due to their efficient pharmacological activities and economic feasibility. Over the ages, medicinal plants have remained a fundamental component of many medications used in the various global health systems to treat a wide range of illnesses (Atanasov et al. 2015). A significant portion of the world's population relies on herbal remedies for benign health conditions, making natural cures for human ailments more common. Due to their safety, herbal medications are gradually taking the place of modern pharmaceuticals, which suggests for further study and testing of their therapeutic qualities. Oxidative stress is the cause of a wide range of degenerative diseases worldwide, hence there is an urgent need for naturally produced antioxidants that are safe and readily obtainable with swift action (Yuan et al. 2016). Beyond their use in food production, plants

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have several advantages, in the medical domain. Many plants are used in the pharmaceutical industry for their medicinal qualities, which are used to treat and prevent diseases. For centuries, the only option available to prevent and treat human ailments was to use plants (Bolouri et al. 2022). Since ancient times, the world has been aware of the plants' therapeutic qualities, which have been passed down both within and between human communities. Even though artificial drugs are widely accessible for medical treatments in today's ultramodern world, people continue to choose traditional herbal remedies owing to their low risks (Erum et al. 2015). Plants' chemical components, which are abundant in biological activity provides their medicinal value (Palombo et al. 2006). Plants are utilized for therapies due to their chemical components, which are abundant in biological activity. Primary and secondary metabolites are the general categories for plant constituents; the latter help the plants survive abiotic stresses (Madouh 2022), and protection against biotic factors such as pests and diseases (Avoseh, 2015). Secondary metabolites in plants are phytochemicals that attract pollinators, act as seed dispersers, UV protectors, and allopathic agents, protect plants from pathogens, insects, and other abiotic stresses, and provide signal molecules for the development of nitrogen-fixing root nodules in legumes (Coley 1987; Crozier et al. 2006). Plant-based phytochemicals are prized as a remedy for human health issues and have drawn a lot of attention due to their potential in the pharmaceutical industry (Zhao 2005).

According to Ana et al. (2022), plant seeds are a major source of nutrients and the origin of several bioactive compounds for people worldwide. Numerous phytochemicals with a broad range of biological activities are found in plant seeds. The active secondary metabolites that are commercially and economically valuable for use in pharmaceutical and medical applications are stored in the seeds of medicinal plants. Globally, the seeds of herbal plants are used for food and medicine, and determining the phytochemical content of these seeds are essential in evaluating their quality (Singh et al. 2017). Strong antioxidant composites found in seeds have been shown to be effective in treating a wide range of disorders, such as diabetes, cancer, and heart-related conditions (Pandey and Rizvi 2009; Pandey 2015). If seeds are proven to have medicinal value, they may be a useful addition to a diet that makes it easy to get enough nutrients each day.

The native plant diversity of the Arabian Peninsula is made up of more than 3,500 species (Ghazanfar and Fisher 1998). In Kuwait, however, the native flora consists of 374 plant species from 55 families that are dispersed throughout a range of habitats (Boulos and Al-Dosari 1994). The native desert plants have developed their own mechanisms for adaptation and tolerance, such as increased lipid and protein synthesis, to ensure that phytochemicals are present and able to withstand a variety of desert stresses (Madouh 2022; Madouh and Quoreshi 2023a).The seeds are the core component of a plant and act as reserves of secondary metabolites, aids desert plants to withstand harsh stresses. Information on the pharmacological benefits of native seeds is essential for its utility as safe medical remedies. To the finest of our understanding, phytochemical analysis of Kuwait native desert plant seeds has not been explored. Therefore, the aim of this study is to identify and quantify the phytochemical contents of the seeds of the native desert plant, *F. aegyptia*, in order to relate to their pharmacological characteristics.

***Farsetia aegytia*:** *Farsetia aegyptia* Turra., (Fig. 1a) is one of the native perennial cruciferous plant of Kuwait, belonging to the Brassicaceae family. Within the kingdom of plants, the family Brassicaceae is regarded as one of the biggest families, and it is renowned for having an abundance of therapeutic herbs. *F. aegyptia* is a flowering plant, greyish white woody perennial about 30-40 cm and covers a meter ground area. This species' native range includes North Africa, the Middle East, the Arabian Peninsula, and North West India. The long-lived perennial desert plants appear to tolerate

Figure 1a. *F. aegpytia* plant*:* 1b. *F. aegyptia* seeds*:* 1c. Seeds surrounded by orbicular reniform with white persistent wings

drought conditions, high temperature and thrive in harsh climates with less than 110 mm of annual rainfall (Madouh, 2023). It grows in a variety of desert habitats and arid environments. *F. aegyptia* is regarded as one of the most promising species for desert landscaping in Kuwait due to its exceptional wind resistance, ability to stabilize sand, and having grey-green foliage. In addition, sheep and camels commonly graze the native desert plant (Suleiman et al., 2020). *F. aegyptia* has medicinal properties and traditionally used by desert habitants as antidiabetic and antispasmodic. It is a remedy for rheumatic aches and used as cooling therapy (Kirtikau and Basu 1975). The plant has anti-cancerous effects and cytotoxic activities against certain selected cancerous cells (Marzouk 2009). The plant extracts exhibited several secondary metabolites: glycosinolates, phenolic acids, and flavonoids such as kaempferol and apienin; flavanols and thier glycosides such as botulin, friedelin, β-amyrin, scopoletin and coumarin. A new flavonoid kaempferol-7, 8-dilucoside was isolated in *F. aegpytia* methanol plant extracts in chromatography analysis (El-Sharkawy et al. 2013). Flavanoids and triterpenes are part of human diet and contribute to anti-cancerous effects. The anti-cancerous potentials of flavanoids in *F. aegyptia* will be promising for cancer chemoprevention and chemotherapy. However, literature review suggests no data on the phytochemical contents of *F. aegyptia* seeds (Fig 1b). The seeds are surrounded by orbicular reniform with white persistent wings (Ismail et al. 2013) (Fig 1c). Using gas chromatography and methanolic seed extracts, the current study intends to identify the phytochemical components and emphasize the medicinal benefits of *F. aegyptia* Turra.

2.Experimental Methodology

2.1.Seed Material: The seeds of *F. aegyptia*, a native desert plant, were collected from a preserved area that is designated as the desert plain ecosystem (Madouh and Quoreshi, 2023b) sited at (29.10°N, 47.42°E) in Kabd, Kuwait. To obtain pure, healthy seeds for the trials, the fruit and seeds were carefully separated. The extra seeds were labeled with their registration number and stored in an airtight container in KISR's seed bank.

2.2. Extraction using ASE (Accelerated Solvent Extraction): The seeds were dried for 48 hours at 30 degrees Celsius, and then were ground into a fine powder with a Polymix grinder (Kinematica, Switzerland). Then the powder was combined (2:1) with diatomaceous earth to remove any remaining moisture. The bioactive compounds were extracted using an ASE 350 system (Dionex, Thermo Scientific, Sunnyvale, CA) and 33 mL stainless steel extraction cells with methanol (99.8%) as the solvent. Four grams of tissue powder were used per cell, per extraction cycle, in the extraction process, which involved solvents at 1500 psi, 100°C, and a five-minute static time. After extraction, the cells

were purged with nitrogen (150 psi for 90 seconds) and washed with new solvent. Three replications of the extraction procedure were carried out, and the extracts were gathered into 66 mL glass vials (Bruce et al. 1996). Following collection, the extracts were combined, filtered, and concentrated in a rotary evaporator operating at a regulated temperature of 45°C while under reduced pressure (Baby Scientific Ltd., Staffordshire, UK).

2.3. GC-MS Analysis: GCMS analysis of the methanolic extract of seeds was analyzed using standard protocols with a High-Resolution Gas Chromatograph Mass Spectrometer-Double Focusing Sector (GC-MS DFS-03030) (Thermo Scientific, Waltham, MA, USA) furnished with a DB-5MS Capillary column. The operating conditions included an initial temperature of 15°C for 1 minute, trailed by levitating it to 280°C over a total analysis time of 56 minutes. The seed extract samples of 1 µl volume were injected in the split less mode injector. Mass spectrometry employed electron impact ionization mode with 70eV energy, and helium grade-5 served as the carrier gas (Irshad et al. 2014). Compound identification in the extract was done by comparing retention times of chromatographic peaks using the National Institute Standard and Technology (NIST) library database (Bagavathi et al. 2012), to compare and identify the compounds.

3.Results

Findings from screening *F. aegyptia* plant seed extracts for phytochemicals indicated the presence of secondary metabolites with various biological characteristics.

Phytochemicals in seeds of Farsetia aegyptia: The *F. aegyptia* seed GC-MS chromatogram showed 21 peaks, indicating the presence of 21 compounds found between 0.88 and 8.63 minutes (Fig. 2). B-D-glucopyranose 1,6-anhydro- (Fig. 3) were found in large amounts in a 26.48 percent peak area at 18.74 minutes and a related sugar, 1,6-Anhydro-B-D-Glucofuranose was detected in minute quantities of 1.08 per cent at 20.38 mins (Fig. 4). Cyclohexanone, Oxime (Fig. 5) and -Furancarboxaldehyde, 5-(Hydroxymethyl (Fig. 6), were detected covering 26.48 and 21.22 per cent area, symbolizing the next compounds present in

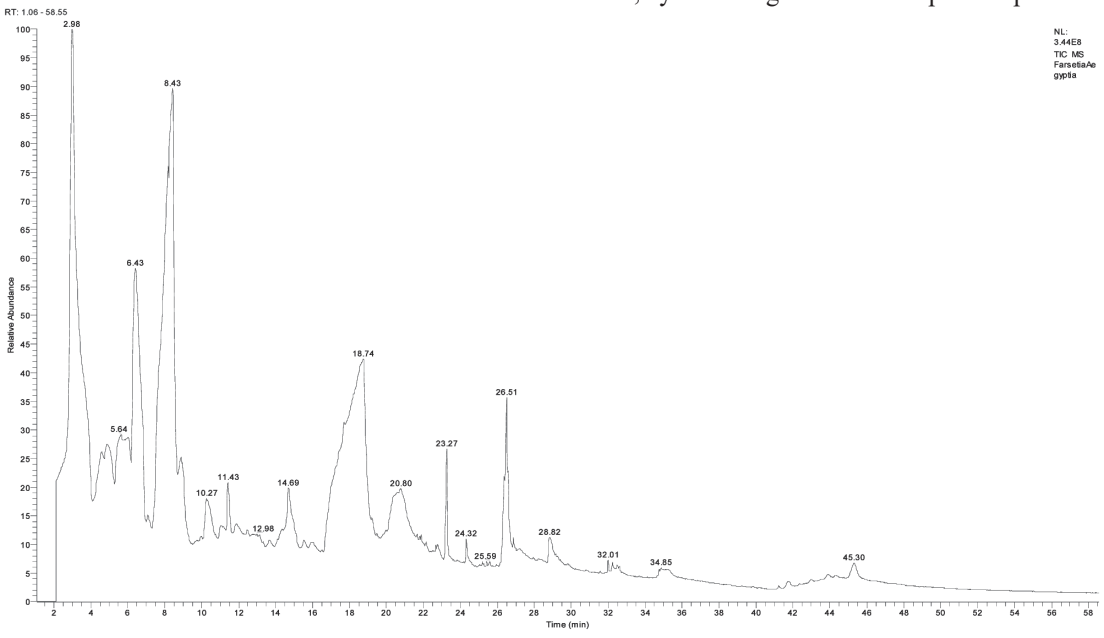

Figure 2. Chromatogram of chemical constituents of *F. aegyptia* seed extracts

Table 1: Chemical constituents of *F. aegyptia* seed extracts

Apex RT	Area	%Area	Library	Formula	MW	Group	Uses	Reference
2.98	4.82E+09	21.22	Cyclohexanone, Oxime	C6H11NO	113	Oxime	Antimicrobial, antifungal,inflammatory -reducing,antioxidant, and anti-cancer properties.	Daoud et al. 1985; Schepetkin et al. 2021; Dhuguru et al. 2022
5.06	5.52E+08	2.43	(1'-Propenyl)Thiophene	C7H8S	124	Nitroalkenes.	Antimicrobial, analgesic, antihypertensive, inflammatory, and antitumor properties.	Shah and Verma, 2013
6.03	1.83E+08	0.81	Pyranone	C6H8O4	144	Unsaturated cyclic esters	Antimicrobial, inflammatory, analgesic, antihypertensive, and antitumor properties.	Chong 2022
6.4	2.68E+09	11.79	Pentanenitrile, 5-(Methylthio)-	C6H11NS	129	Nitriles	Agents with anti-inflammatory or anti-cancer properties; building blocks for the synthesis of different compounds.	Ki et al. 2014
8.43	4.76E+09	20.96	2-Furancarboxaldehyde, 5-(Hydroxymethyl	C6H6O3	126	Aldeyde	Antibacterial, anticancer, and antioxidant properties; antagonistic substances that prevent the growth of biofilms in pathogenic fungus; has the potential to be used in innovative ways in the pharmaceutical sector; used to treat sickle cell disease, a collection of hereditary disorders affecting red blood cells. It has antioxidant properties.	Phutdhawong et al. 2021; Abdulmalik et al. 2005; Ganapathy et al., 2018; Chen et al., 2014
8.87	1.25E+08	0.55	Cyclopentanone, 3-Ethenyl-2,4,4-Trimethyl-	C10H16O	152	Cyclic ketones	Used in the cosmetics industry to make decorative cosmetics, high-quality fragrances, shampoos, soaps, and detergents; has antioxidant and antibacterial properties.	Wei and Zhang, 2023; Belsito et al., 2012
10.27	4.2E+08	1.85	1,3-Dipropylurea	C7H16N2O	144	Carbamide	It has anticancer properties and is used as a reagent in the pharmaceutical and agrochemical industries to synthesize different organic compounds.	Therese et al., 2020
11.43	2.61E+08	1.15	Ethyl 4-Bromo-3-Phenylbut-2-Enoate	C12h13bro2	268	Cinnamic acid esters.	Activities that include anti-inflammatory, antidiabetic, anti-cancer, antimicrobial, and neuroprotective properties; utilized in the fragrance and flavor sector.	Jawaher et al., 2022; Koichi et al., 2017
14.69	3.58E+08	1.58	8h-Pyrido[1,2-A], Pyrazin-8-One, 1,2,3, 4-Tetrahydro-9-Hydroxy-1-Methyl-	C9H12N2O2	180	Pyridol	Parkinson's disease treatment.	Temitayo et al., 2021
18.74	6.02E+09	26.48	Â-D-Glucopyranose, 1,6-Anhydro-	C6H10O5	162	Class of anhydro sugars -Anhydrohexose	Hepatoprotective, antitumor, and antioxidant agent that guards against liver toxicities; utilized in the synthesis of bioethanol; utilized as a marker for the combustion of wood and coal; utilized as a chemical tracer in atmospheric chemistry research to monitor biomass burning.	Chang et al., 2017,2021; Gaudin et al. 2017; Harrison et al., 2013; Praveena et al., 2010; Yan et al., 2018
20.38	2.45E+08	1.08	1,6-Anhydro-Â-D-Glucofuranose	C6H10O5	162	Sugar	Antimicrobial, antiviral, and antitumor properties; it has the ability to combat Gram-positive bacteria through antibacterial activity. Humans benefit from this source of 5-hydroxymethyl furfural (HMF) because it is nutritious. HMF contributes to the inhibition of cancer cell growth in vitro.	Cymit 2023; Ma³gorzata et al., 2017
23.27	3.71E+08	1.63	Hexadecanoic Acid	C16H32O2	256	Saturated long-chain fatty acid	Reduces the levels of cholesterol in the body by having antimicrobial, antihypoxic, antimutagenic, fibrinolytic, anti-inflammatory, antisecretory, cryopreservatic, anesthetic, antioxidant, and hypochlorestolemic properties.	Agoramoorthy et al. 2007; Karthikeyanetal 2019; Vasudevan et al. 2012
24.32	77685639	0.34	Peroxydihydro costunolide	C15H22O4	266	Sesquiterpene lactones	Possible anti-cancer agent for breast, lung, and colon cancer, among other cancer types; the properties of this substance include anti-aging, anti-inflammatory, antiallergic, bone remodeling, neuroprotective, growth promoting, anticancer, hair growth and antidiabetic effects.	Lee et al. 2021; Kim and Choi, 2019; Chaturvedi et al. 2011
26.51	1.28E+09	5.64	Cis-Vaccenic Acid	C18H34O2	282	Fatty acid	Effects that are antibacterial, hypolipidemic, antifungal, antitubercular, anticancer, antioxidant, and have other preventive properties.	Fagbemi et al. 2022; Qadir et al. 2020; Semwal et al. 2018; Hamazaki et al. 2016
28.82	2.45E+08	1.08	Â-D-Galactopyranoside, Methyl 2,6-Bis-O-(Trimethylsilyl)-, Cyclic Methylboronate	C14H31BO6Si2	362	Monosaccharide	Bactericidal action antimicrobial, antidiabetic, antioxidant, and antihyperlipidemic effect.	Islam et al. 2022; Kumar et al. 2013; Olena et al. 2011;

Apex RT	Area	%Area	Library	Formula	MW	Group	Uses	Reference
32.01	29349934	0.13	2-Methyl-4-Phenyl-3h-Pyrido[1,2-B] Pyridazin-3-One	C15H16N2O	240	Pyridazine derivatives	Blood platelet aggregation inhibitors, antimicrobial, anti-inflammatory and analgesic, anti-HIV, antiplasmodial, antitubercular, antibacterial, anticonvulsant, COX inhibitor, antidiabetic, antihypertensive, anticancer effects, antioxidant, antitumor, and antifungal activities antibacterial action.	Ibrahim and Behbehani 2014; Dubey et al 2015
41.22	10838239	0.05	Phosphorin, 1, 1-Dihydro-1-Methyl-2,4,6-Triphenyl-1-(2-Propynyloxy	C27H23OP	394	Phosphoryl group	In organic chemistry, it is employed as a mild oxidizing and reducing agent with antimicrobial activity, cytotoxicity, antibacterial, and anti-inflammatory qualities.	Mohammed et al. 2019; Prado et al. 2015; María et al. 2008
41.75	48898294	0.22	(5á,6á)-4,5-Epoxy-17-Methyl-3-Phthalimidomorphinan-6-Ol	C25H24N2O4	416	Morphinan Alkaloid	Pharmaceutically useful substances;analgesics are currently used to treat chronic and moderate-to-severe pain. Antitussive and analgesic effects.	Tanila et al. 2014; Elena et al. 2014; Fossati et al. 2014;
42.96	17332348	0.08	26-Homo-25-Hydroxy cholesterol	C28H48O2	416	Steroid	Used as a nervous system signaling molecule.	Odnoshivkina 2022
43.88	28653532	0.13	Ethyl Iso-Allocholate	C26H44O5	436	Steroidal Derivative	Antimicrobial activity.	Muthulakshmi et al. 2012
45.3	1.86E+08	0.82	24(Z)-Methyl-25-Homocholesterol	C29H50O	414	Phytosterol	Anticarcinogenicity and antimutagenicity properties.	Chariyakornkul et al. 2021

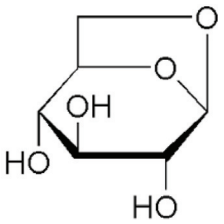

Figure 3. Â-D-Glucopyranose, 1,6-Anhydro (26.48 %)

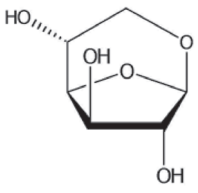

Figure 4. 1,6-Anhydro-Â-D-Glucofuranose (1.08 %)

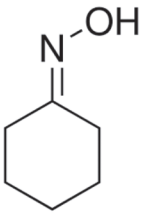

Figure 5.Cyclohexanone, Oxime (21.22 %)

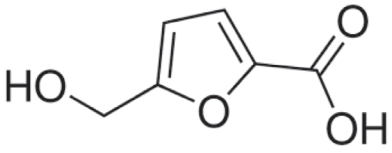

Figure 6. -Furancarboxaldehyde, 5-(Hydroxymethyl (20.96 %)

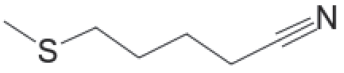

Figure 7. Pentanenitrile, 5-(Methylthio)- (11.79 %)

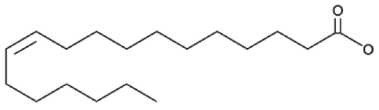

Figure 8. cis-Vaccenic Acid (5.64 %)

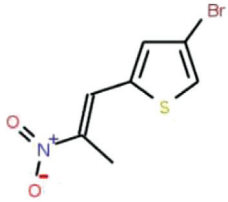

Figure 9. (1'-Propenyl) Thiophene (2.43%)

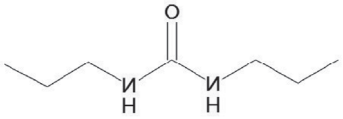

Figure 10. 1,3-Dipropylurea (1.85%)

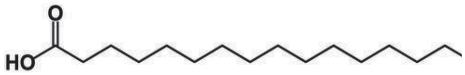

Figure 11. Hexadecanoic Acid (1.63%)

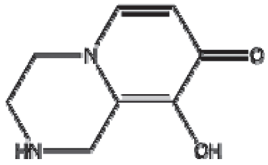

Figure 12. 8h-Pyrido[1,2A]Pyrazin-8-One, 1,2,3,4-Tetrahydro-9-Hydroxy-1-Methyl- (1.58 %)

bulk quantities sensed at 2.98 and 8.43 mins respectively. Pentanenitrile, 5-(Methylthio)- (Fig. 7), Cis-Vaccenic Acid (Fig. 8), and (1'-Propenyl) Thiophene (Fig. 9), were spotted at next level in an area of 11.79, 5.64 and 2.43 per cent at 6.4, 26.51 and 5.06 mins.1,3-Dipropylurea (Fig. 10), Hexadecanoic Acid (Fig. 11) 8h-Pyrido[1,2-A] Pyrazin-8-One, 1,2,3,4-Tetrahydro-9-Hydroxy-1-Methyl (Fig. 12), Ethyl 4-Bromo-3-Phenylbut-2-Enoate, and Â-D-Galactopyranoside, Methyl 2,6-Bis-O-(Trimethylsilyl)-, Cyclic Methylboronate were distinguished in minute quantities occupying

1.85, 1.68, 1.58, 1.15, 1.08 and 1.08 percent are at 10.27, 14.69, 11.43, and 28.82 per cent respectively (Table 1). Few more compounds were also perceived in the chromatogram in minor levels.

4. Discussion

The role of therapeutic native flora in treating various health disorders is constantly in rise, due to their exclusive chemical components enriched with biological activities (Silva et al. 2010).Native herbs are used medicinally by the vast majority of people, either directly or indirectly. Compounds with physiological responses or therapeutic effects have been identified through the phytochemical evaluation of several native desert plants (Madouh 2022; Madouh and Quoreshi 2023a). The current study on a particular native plant seed extract from Kuwait, verified the presence of multiple secondary metabolites, including alkaloids, flavonoids, saponins, steroids, sterols, and phytosterols, that may have therapeutic value. The investigated native plant *F. aegyptia* is a member of the Brassicaceae family and is a shrub or herb that is commonly found in the arid regions or desert ecosystems. It is likely that native desert plants, and *F. aegyptia* in particular, produce a variety of secondary metabolites that have significant physiological and ecological effects (Madouh 2022) in order to defend themselves against exogenous abiotic constraints.

The family comprises 4060 accepted species and 372 genera, which include several economically significant plants and is renowned for the richness of its phytochemicals and nutritional makeup (Samec 2019). They promote better health because they are high in fiber, vitamins, and minerals and low in fat (Dias 2012). They are highly rich source of phytochemicals that help prevent chronic diseases, such as phenolic compounds and isothiocyanates. The multiple anticancer mechanisms of the organosulphur compound isothiocyanate, which include changes in drug metabolizing enzymes that modify the chemical carcinogenesis process, induction of cell cycle arrest and apoptosis with antioxidant, anti-inflammatory, and immunomodulatory activities, are responsible for the compound's chemopreventive properties (Camargo et al. 2016; Dinkova-Kostova et al. 2012).Owing to its antioxidant properties, it guards against oxidative damage caused by reactive oxygen species (ROS). Phenolic compounds, another significant member of the family, have been identified as potent antioxidants (Samec 2019). The presence of glucosinolates in cruciferous plants may help prevent a number of deadly human diseases, including cancer, according to mounting scientific evidence (Soengas, et al. 2011). Indole-3-carbinol, a byproduct of glucobrassicin hydrolysis, is the most studied anticancer agent in cruciferous plants (Soundararajan, 2018). Additionally, it is claimed to have gastroprotective, anti-inflammatory, anti-diabetic, anti-obesity, and antioxidant properties that are beneficial to human health. Furthermore, it has insecticidal, antifungal, and antibacterial properties that promote crop production by thwarting pests and illnesses (Sarvan 2017). Some of the plants in the family are currently used in powder, pellet, or decoction form, has been used to treat a variety of animal ailments, improving animal health as well (Tripathi et al 2003; Tripathi and Mishra 2017). The plant, contains enzymes such as amylase, which is necessary for animals to properly metabolize starch.

Phytochemical diversity in *F. aegyptia* seeds:The evaluation of the seed extracts of *F. aegyptia,* for phytochemicals to comprehend its medicinal value, revealed the presence of 21 compounds detected at 0.88 - 8.63 mins of retention time. Researchers have previously confirmed that *F. aegyptia* seed extracts contain a variety of biochemicals, including sugars, fatty acids, alkaloids, steroids, ketones, esters, aldehydes, amides, alkenes, oximes, and nitriles (Marzouk et al. 2008; Marzouk et al. 2020; Al-Shehbaz et al. 2006; Al-Gendy 2003). The current study revealed greater concentrations of the anhydrous sugar B-D-Glucopyranose, 1, 6-Anhydro- (Fig. 3) with a detection rate of 26.48% at 18.74 minutes. The main byproduct of pyrolysis

of cellulose is B-D-glucopyranose, 1,6-Anhydro-, or levoglucosan (Ivaldo et al. 2020). Levoglucosan hydrolyzes to produce glucose, a fermentable sugar that is the main source of energy for all living things. Glucopyranose, an energy-boosting substance, makes up the cyclic configuration of glucose. The availability of a plentiful supply of glucose is a positive indication that native seed intake can provide humans with natural energy instead of relying on artificial sources. Furthermore, it has antitumor, antioxidative, and hepatoprotective properties that guard against liver toxicities (Chang et al. 2017; Gaudin et al. 2017; Harrison et al. 2010; Praveena et al. 2010). The compound plays a part in the production of bioethanol, which is a major alternative to gasoline due to its rising cost. Levoglucosan (B-D-Glucopyranose, 1,6-Anhydro) is the most prevalent and alluring substrate for bioethanol fermentation, in bioethanol fuel production (Al-Gendy et al. 2003). As levoglucosan functions as a chemical tracer of biomass in studies on atmospheric chemistry, it plays a significant part in air pollution monitoring. In the combustion of coal and wood, it serves as a marker (Gaudin et al. 2017). Through qualitative and quantitative research, the potential of native plant seeds as an atmospheric marker can be further explored. During 20.38 minutes of retention time, a related compound 1,6-Anhydro-B-D-Glucofuranose (Fig. 4) was found in 1.08 %. In contrast to pyranoses, which have six membered rings with five carbon atoms and one oxygen atom, furanoses are carbohydrates with five membered rings made up of four carbon atoms and one oxygen atom. Fructose is a common furanose; furanoses are less common than pyranoses. Antimicrobial, antiviral, and antitumor properties have been reported for B-D glucofuranose (Cymit 2023; Malgorzata 2017). An encouraging feature is that it also exhibits antibacterial activity against Gram positive bacteria. The substance serves as a source of 5-hydroxymethyl furfural (HMF), which provides food value for people. HMF is a compound that inhibits cancer cell growth in vitro and causes UV radiation to kill off cancer cells (Phutdhawong et al. 2021; Abdulmalik et al. 2005; Ganapath et al. 2018; Chen et al. 2014). Due to its antibacterial and anticancer properties, the compound B-D, glucofuranose, helps provide nutritional value to humans despite being present in small amounts in *F. aegyptia* seeds. Extensive therapeutic actions, including antibacterial, antifungal, anti-inflammatory, antioxidant, and anti-cancer effects, were also observed in *F. aegyptia* seed extracts (21.22 %) perceived at 2.98 minutes, exhibiting the cyclohexnone oxime (Fig. 5) (Daoud et al. 1985; Schepetkin et al. 2021; Dhuguru et al. 2022). Oximes, which are recognized for their antioxidative, anticancer, antimicrobial, and anti-inflammatory properties, are typically effective bioactive compounds with many applications in the medical field and potential biological activity (Alicja et al. 2020). Additionally, it is recommended as a remedy for organophosphate toxicity (Ivaldo et al. 2020).

The arylaldehyde 2-furancarboxaldehyde, 5-(hydroxymethyl) (Fig. 6) covers an area of 20.96% detected at 8.43 minutes and is said to have potential for novel applications in the pharmaceutical industry. It contains an aldehyde group directly attached to an aromatic ring. It is known that aldehyde is a common component of all living things, including bacteria and humans. It elicits antagonistic agents that prevent pathogenic fungi from forming biofilms, and it has potent antioxidative, antibacterial, and anticancer properties. It is used to treat sickle cell disease, a collection of hereditary disorders affecting red blood cells. Accordingly, the phytochemical has a good chance of finding novel uses in the pharmaceutical sector (Phutdhawong et al. 2021; Abdulmalik et al. 2005; Ganapathy et al. 2018; Chen et al. 2014). *F. aegyptia* seed extracts contained a nitrile called Pentanenitrile, 5-(Methylthio)- (Fig. 7), which occupies 11.79% of the area in 6.4 minutes and is used as a building block for the synthesis of different compounds. It is discovered that the methylthio-butanyl derivative has anti-inflammatory and anti-cancer properties (Ki et al. 2014). The substance

has antifungal properties against fungi that cause plant damage (Arya et al. 2021). Cis-Vaccenic acid (Fig. 8), a fatty acid that belongs to the long chain fatty acid class and is also referred to as vaccenate or asclepic acid, is an isomer of vaccenic acid. It was found in medium quantities of 5.64 per cent in 26.51 minutes (Fagbemi et al. 2022). It includes prophylactic activities, antioxidant properties, antitubercular, antibacterial, antifungal, anticancer, and hypolipidemic effects (Qadir et al. 2020; Semwal et al. 2018).

A nitroalkene 1'-Propenyl Thiophene, (Fig. 9) was found at 5.06 minutes, covering 2.43 % of the area. It was reported to have strong antimicrobial activity against a range of microbial infections. Additionally, it has pharmacological qualities that include antimicrobial, analgesic, inflammatory, antihypertensive, and antitumor activity (Shah et al. 2018). 1,3-Dipropylurea (Fig. 10), a carbamide with anticancer properties, is found in small amounts (1.85% of the area) and is used as a reagent in the synthesis of various organic compounds in the agrochemical and pharmaceutical industries. The saturated long-chain fatty acid hexadecenoic acid (Fig.11) is said to have great potentials in therapies with antimicrobial, antihypoxic, antimutagenic, fibrinolytic, anti-inflammatory, antisecretory, cryopreservatic, anaesthetic, antioxidant, and hypochlorestolemic activity, as well as lowering the body's cholesterol level. It is detected in an area covering 1.63% at 23.27 minutes. To control soft-bodied insects, it is applied as an herbicide and insecticide in agriculture (Cymit 2023; Ma^{3}gorzata 2017). A pyridol, 8h-Pyrido[1,2-A]Pyrazin-8-One, 1,2,3,4-Tetrahydro-9-Hydroxy-1-Methyl- (Fig 12) was detected at 14.69 minutes in 1.58 % area, is utilized for treatment of Parkinsons disease according to previous research (Temitayo 2021). In formulations, it also serves as an adjuvant and additive. Potential therapeutic effects are associated with ethyl 4-Bromo-3-Phenylbut-2-Enoate, a cinnamic acid ester that was detected in an area of 1.15 percent at 11.43 minutes. It has anti-inflammatory, antidiabetic, anti-cancer, antimicrobial, antioxidant, and neuroprotective properties. It is also employed in the flavor and fragrance industries (Jawaher et al. 2022; Koichi et al. 2017). Methyl 2,6-Bis-O-(Trimethylsilyl)-, Cyclic Methylboronate, B-D-Galactopyranoside, and other monosaccharides were found in 1.08 percent of the sample in 28.82 minutes. These compounds are powerful therapeutic agents that have antimicrobial, antidiabetic, and antioxidant properties (Bayan et al. 206). It is claimed in a study by Olena et al. (2011) to have antibacterial activity.

Several other compounds were detected in traces, with potent therapeutic effects. A steroid 26-Homo-25-Hydroxycholesterol, a neuronal signaling molecule with anticarcinogenic and antimutagenic properties, was detected in 0.82% quantity (Chariyakornkul et al. 2020). Pyranone, an unsaturated cyclic ester with antitumor activity, was discovered in trace amounts of 0.81 % and shows great promise for use in biomedical and material sciences applications(Chong et al. 2022). Strong cytotoxic, antibiotic, antihyperglycemic, and antifungal properties are displayed by the compound(Mishra et al. 2021).

A cyclic ketone known as cyclopentanone, or 3-Ethenyl-2,4,4-Trimethyl, was found in traces of 0.55 %. This compound has antibacterial and antioxidant properties and is used in the cosmetics industry to make detergents, shampoos, soaps, and decorative cosmetics (Wei and Zhang, 2023; Belsito et al. 2012; Therese et al. 2020). An antioxidative, anti-inflammatory, antiallergic, bone-remodeling, neuroprotective, hair-growth-promoting, and antidiabetic sesquiterpene lactone known as peroxydihydro costunolide was observed in minute quantity of 0.34% (Lee et al. 2024; Kim et al. 2019). It may be used as an anti-cancer treatment to treat breast, lung, and colon cancer, among other cancers. A morphinan alkaloid, (5α, 6α)-4,5-Epoxy-17-Methyl-3-Phthalimidomorphinan-6-Ol, which is used as a therapeutically valuable drug and has analgesic and antitussive activity to treat moderate to severe and chronic pain, was detected in 0.22 per

cent. A pyridazine derivative, 2-Methyl-4-Phenyl-3h-Pyrido[1,2-B]Pyridazin-3-One that possess antimicrobial, anti-inflammatory, analgesic, anti-HIV, antiplasmodial, antitubercular, antibacterial, anticonvulsant, COX inhibitor, antidiabetic, antihypertensive, anticancer effects, blood platelet aggregation inhibitors, antidepressant and anxiolytic, antioxidant, antitumor and antifungal activities (Ibrahim and Behbehani, 2014; Dubey et al. 2015) and a steroidal derivative, ethyl iso-allocholate wit antimicrobial activity (Elena et al. 2014) was sensed in 0.13 %. A phosphoryl compound, Phosphorin, 1,1-Dihydro-1-Methyl-2,4,6-Triphenyl-1-(2-Propynyloxy used as a mild oxidizing agent, reducing agent in organic chemistry with anti-inflammatory antimicrobial activity and cytotoxicity was sensed in 0.05 per cent (Mohammed et al. 2019; Prado et al. 2016; María et al. 2006).

The current investigation brought the therapeutic effects of *F. aegyptia* seeds to light, paving its possibilities to utilize in pharmaceutical industries. The seeds of this species reserved a bulk of secondary metabolites in store, that have synthesized due to the multiple stresses in Kuwait terrestrial habitats in desert ecosystem (Madouh and Quoreshi, 2023b). Researches revealed that stresses related to desert such as drought, salinity, high temperature etc. induce the plant to produce secondary metabolites as a defense mechanism to protect themselves from harsh stresses (Madouh, 2022; Madouh and Quoreshi, 2023a). Most of the detected phytochemicals in *F. aegyptia* seeds were found to possess therapeutic effects, which was earlier corroborated by several researchers (Marzouk et al. 2009; El-Sharkawy et al. 2013; Marzouk et al. 2020; Al-Shehbaz et al. 2006; Ibrahim et al. 2006; Anjum et al. 2015, Atta et al. 2013). The genus *Farsetia* is reported for its traditional therapeutic potentials in treating diabetes, gastrointestinal problems and other infectious diseases (Hayat and Uzair, 2019). In traditional folk medicine it plays a role as anti-alphaglucosidase, anti-chymotrypsin, anti-urease, antibacterial, anti-fungal, antimicrobial, anti-proliferative, anti-oxidant, anti-inflammatory activities (Ahmad et al. 2014). In Kuwait, the plant parts are used to treat oral infections related to tooth and mouth, as a disinfectant and used to treat sore eyes. The phytochemicals in *F. aegyptia* seeds suggest its utility for oral intake as a natural remedy for diseases. Future research on the pharmacological characteristics of the detected compounds and the separation of active compounds from seed extracts is essential for the valuable native plants to be used effectively as a source of novel drugs to treat human and animal health disorders.

For decades, the search for novel drugs to treat human diseases has focused more on natural products because of the unfavorable side effects, exorbitant cost, and inefficiency of current treatments. Due to their distinct chemical diversity, which has developed over millions of years, natural products have a wide range of biological activities and drug-like qualities. They are now among the most crucial tools for creating novel scaffolds and lead compounds. Natural products will be used continuously in an effort to address the pressing need to create effective medications, and they will take the lead in the search for medications that treat human illnesses, particularly serious diseases (Galm et al., 2007). Our study exposed the existence of potential phytochemicals with therapeutic effects in *F. aegyptia* seeds. However, more research is required to quantify the phytochemicals with pharmacological features by standard methodologies and assess them for their therapeutic effects.

5. Conclusion

In the current study, the phytochemical profile of a particular native plant from the desert ecosystem of Kuwait, *F. aegyptia,* was found to contain 21 compounds, almost all of which had the potential to treat deadly human diseases. Higher amounts of B-D-Glucopyranose, 1, 6-Anhydro-, which can act as a natural energy source, were found in *F. aegyptia*

seeds (26.48%). It is a hepatoprotective agent that guards against liver toxicities and exhibits antitumor and antioxidant properties. B-D glucofuranose, a related sugar, has been found to possess strong antibacterial, antiviral, and antitumor effects. The presence of Cyclohexnone oxime, which has a multitude of therapeutic actions including antibacterial, antifungal, anti-inflammatory, antioxidant, and anti-cancer properties, was also noted in large quantities in *F. aegyptia* seed extracts (21.22%). Another compound found in higher concentrations (20.96%) in *F. aegyptia* seeds is an arylaldehyde called 5-hydroxymethyl furancarboxaldehyde, with beneficial medicinal properties including anticancer, antibacterial, and antioxidant properties. Pentanenitrile, 5-(Methylthio)-, a nitrile that accounted for 11.79 percent of the extracts from *F. aegyptia* seeds, has been shown to have anti-inflammatory and anti-cancer properties. Found in *F. aegyptia* seeds, Cis-Vaccenic acid is a fatty acid that possesses antibacterial, antifungal, antitubercular, anticancer, antioxidant, hypolipidemic, and other prophylactic properties. The saturated long-chain fatty acid, hexadecenoic acid that has great potential in therapies possessing antimicrobial, antihypoxic, antimutagenic, fibrinolytic, anti-inflammatory, antisecretory, cryopreservatic, anaesthetic, antioxidant, and hypochlorestolemic activity was sensed in *F. aegyptia* seeds as well. A carbamide, 1,3-Dipropylurea, has anticancer properties. A nitroalkene, (1'-Propenyl) Thiophene, is reported to have pharmacological properties such as antimicrobial, analgesic, inflammatory, antihypertensive, and antitumor activity. The majority of the identified compounds of *F. aegyptia* seeds were discovered to have a range of therapeutic effects; more research is required to determine its effectiveness. Therefore, *in vivo* assays and clinical trials are necessary for the safety and efficacy recognition of *F. aegyptia* seeds. Investigations on their dosage to cure various fatal diseases should also be progressed. Consequently, results obtained from the existing study by phytochemical evaluation, can lead to the formulation of a promising herbal capsule formulation. In Kuwait, this plant is regarded as one of the valuable native species, so further research into its components for pharmacological utility as natural medicine is worthwhile.

Availability of data and materials

Herbaria of plant specimen of *F. aegyptia* and the identification information sheets are stored in the Seed Bank, Kuwait Institute for Scientific Research (KISR) and can be retrieved when necessary. Data supporting this manuscript are protected in databases of seed bank, ELSRC, KISR and are available from the corresponding author on reasonable request.

Acknowledgements

The authors gratefully acknowledge the Kuwait Institute for Scientific Research (KISR) for providing facilities and encouragement, and the Kuwait Foundation for the Advancement of Sciences (KFAS) for providing assistance in supporting the scientific research. The staff of the Desert Agriculture and Ecosystem Program (DAEP) laboratory deserves special recognition for their helpful support in conducting this research.

References

Abdulmalik, O., Safo, M.K., Chen, Q., Yang, J., Brugnara, C., Ohene-Frempong, K., Abraham, D.J. and Asakura, T. 2005. 5-hydroxymethyl-2-furfural modifies intracellular sickle haemoglobin and inhibits sickling of red blood cells. Br J Haematol., 128(4):552-61. doi: 10.1111/j.1365-2141.2004.05332.x.

Agoramoorthy, M., Chandrasekaran, V. and Venkatesalu, M.J.H. 2007. Antibacterial and antifungal activities of fatty acid methyl esters of the blind-your-eye mangrove from India. Braz. J. Microbiol., 38: 739–742.

Ahmad, S., Alam, K., Waris, H.M., Anjum, S.and Mukhtar, M. 2014. Ethnobotanical studies of plant resources of Cholistan desert, Pakistan. Int. J. Sci. Res., 3: 1782.

Al-Gendy, A.A. and Lockwood, G.B. 2003. GC-MS analysis of volatile hydrolysis products from glucosinolates in *Farsetia aegyptia* var. *ovalis.* Flavour and Fragrance Journal. 18(2): 148-152. https://doi.org/10.1002/ffj.1163.

Alicja, K.S., Stanis³aw, L. and Daniel, J.S. 2020. Unsubstituted Oximes as Potential Therapeutic Agents. Symmetry., 12(4): 575; https://doi.org/10.3390/sym12040575.

Al-Shehbaz, I.A., Beilstein, M.A. and Kellogg, E.A. 2006. Systematics and phylogeny of the *Brassicacaceae* (Cruciferae): an overview. Plant Syst. Evol. 259: 89–120.

Ana, C., Pravin, K.S., Suryakant, C., Yaman, K., Sahu, K., Singh, P., Samarendra, S., Erick, K.T., Pablo, M., José, J., Quesada-Granados, J. and Rufián-Henares, A.2022. Plant seeds as source of nutrients and phytochemicals.International Journal of Food Science and Technology., 57: 525–532doi:10.1111/ijfs.15414.

Anjum S. 2015. Phytochemical Evaluation of *Farsetia hamiltonii* Royle from Cholistan Desert. J.Chem.Soc.Pak., 37: 335.

Arya, A.S., Hang, M.T.H. and Eiteman, M.A. 2022. Isolation and Characterization of Levoglucosan-Metabolizing Bacteria. Appl Environ Microbiol., 22;88(4):e0186821. doi: 10.1128/AEM.01868-21. Epub 2021 Dec 15. PMID: 34910566; PMCID: PMC8863068.

Atanasov, A.G., Waltenberger, B., Pferschy-Wenzig, E.M., Linder, T., Wawrosch, C., Uhrin, P., Temml, V., Wang, L., Schwaiger, S., Heiss, E.H., Rollinger, J.M., Schuster, D., Breuss, J., Bochkov, V., Mihovilovic, M.D., Kopp, B., Bauer, R., Dirsch, V.M. and Stuppner, H. 2015. Discovery and resupply of pharmacologically active plant-derived natural products: A review. Biotechnol Adv 2015; 33(8):1582-1614. doi: 10.1016/j.biotechadv.2015.08.001.

Atta, E., Hashem, A. and Elsharkawy, E. 2013. A novel flavonoid compound from *Farsetia aegyptia* and its antimicrobial activity. Chemistry of Natural Compounds. 49. 10.1007/s10600-013-0631-z.

Avoseh, O., Oyedeji, O., Rungqu, P., Nkeh-Chungag, B., Oyedeji, A. 2015.Cymbopogon species; ethnopharmacology, phytochemistry and the pharmacological importance. Molecules. 20:7438–7453.

Bagavathi, P.E. and Ramasamy, N. 2012. GC-MS analysis of phytocomponents in the ethanol extract of Polygonum chinense L. Pharmacognosy Res. 4: 11-14. https://doi.org/10.4103/0974-8490.91028.

Bayan, Y. 2016. Chemical composition and antifungal activity of the plant extracts of Turkey, Cardaria Draba. Egyptian Journal of Biological pest Control. 26(3): 579-581.

Belsito, D.D., Bickers, M., Bruze, P., Calow, M.L., Dagli, W., Dekant, A.D., Fryer, H., Greim, Y., Miyachi, J.H., Saurati, I.G. and Sipes, J. 2012. A toxicologic and dermatologic assessment of cyclopentanones and cyclopentenones when used as fragrance ingredients Food and Chemical Toxicology. 50(S517)-S(556).

Bolouri, P., Salami, R., Kouhi, S., Kordi, M., Asgari, S., Lajayer, B., Hadian, J. and Astatkie, T. Applications of essential oils and plant extracts in different industries. Molecules 2022; 16;27(24):8999. doi: 10.3390/molecules27248999. PMID: 36558132; PMCID: PMC9781695.

Boulos, L. and Al-Dosari, M. Checklist of the flora of Kuwait. Journal of Kuwait University (Sciences). 1994; 21: 203- 217.

Bruce, E.R., Brian, A.J., John, L.E., Nathan, L.P., Nebojsa, A. and Chris, P. 1996. Accelerated Solvent Extraction: A Technique for Sample Preparation. Anal. Chem 68: 1033-1039. https://doi.org/10.1021/ac9508199.

Camargo, A.B., Manucha, W. 2016. Potential protective role of nitric oxide and Hsp70 463 linked to functional foods in the atherosclerosis. Clínica e Investigación En 464 Arterosclerosis. 29(1): 36-45.

Chang, D., Zia, U.., Zhiguang, Y., Ian, P. T. and Zhisheng, Yu. 2021. Conversion efficiency of bioethanol from levoglucosan was improved by the newly engineered. 40(6). https://doi.org/10.1002/ep.13687.

Chang, W., Li, Y., Zhang, M., Zheng, S., Li, Y. and Lou, H. 2017. Solasodine-3-O-bD-glucopyranoside kills Candida albicans by disrupting the intracellular vacuole. Food Chem Toxicol. 106:139–46.

Chariyakornkul, A., Nichanan, I., Sirinya, T. and Rawiwan, W. 2021. Low-polar extract from seed of *Cleistocalyx nervosum* var. *paniala* modulates initiation and promotion stages of chemically-induced carcinogenesis in rats, Biomedicine Pharmacotherapy. 133: 110963, ISSN 0753-3322,https://doi.org/10.1016/j.biopha.2020.110963.

Chaturvedi, D. 2011.Sesquiterpene lactones: Structural diversity and their biological activities. Opportunity, Challenge and Scope of Natural Products in Medicinal Chemistry, 313-334 ISBN: 978-81-308-

0448-4.

Chen, P.X., Tang, Y., Zhang, B., Liu, R., Marcone, M.F., Li, X. and Tsao R. 5-hydroxymethyl-2-furfural and derivatives formed during acid hydrolysis of conjugated and bound phenolics in plant foods and the effects on phenolic content and antioxidant capacity. J Agric Food Chem. 2014; 21:62(20):4754-61. doi: 10.1021/jf500518r. Epub 2014 May 12. PMID: 24796380.

Chong, Y.Y.N., Huanhua, C.S., Liang MS, Yuehu P. and Haifeng W. 2022. Pyranone Derivatives with Antitumor Activities, From the Endophytic Fungus Phoma sp. YN02-P-3. Front. Chem., Sec. Medicinal and Pharmaceutical Chemistry. 10. | https://doi.org/10.3389/fchem.2022.950726.

Coley, P.D. 1987. Interspecific variation in plant anti-herbivore properties: The role of habitat quality and rate of disturbance. New Phytol 106: 251–263.

Crozier, A., Jaganath, I.B. and Clifford, M.N. 2006. Phenols, polyphenols and tannins: An overview. In Plant Secondary Metabolites: Occurrence, Structure and Role in the Human Diet; Blackwell Publishing: Oxford, UK.

Cymit. 2023.https://cymitquimica.com/products/3D-MA44750/7425-74-3/16-anhydro-b-d-glucofuranose/. 2023.

Daoud, H.S. and Al-Rawi, A. 1985. Flora of Kuwait 1: 1-224. Alden Press Ltd.

Dhuguru, J., Zviagin, E. and Skouta, R. 2022. FDA-Approved Oximes and Their Significance in Medicinal Chemistry. Pharmaceuticals. 15: 66.

Dias, J.S. 2012. Nutritional quality and health benefits of vegetables: A review. Food and 482 Nutrition Sciences. 3(10): 1354.

Dinkova-Kostova, A.T. and Kostov, R.V. 2012. Glucosinolates and isothiocyanates in health and disease. Trends Mol Med. 2012; 18(6):337-47. doi: 10.1016/j.molmed.

Dubey, S. and Bhosle, P.A. 2015. Pyridazinone: an important element of pharmacophore possessing broad spectrum of activity. Med Chem Res. 24: 3579–3598. https://doi.org/10.1007/s00044-015-1398-5.

Elena, F., Lauren, N., Andrew, E., Jean-Pierre, F., Vincent, S. and Martin, J. 2014. Synthesis of Morphinan Alkaloids in *Saccharomyces cerevisiae*. https://doi.org/10.1371/journal.pone.0124459.

El-Sharkawy, E., Azza, A.M. and Emad, M.A. 2013. Cytotoxity of New Flavonoid Compound Isolated from *F. aegyptia*. Int J Pharm Sci Inven 2:23.

Erum, I., Kamariah, A.S., Linda, B.L. and Lim, S. 2015. Phytochemical screening, total phenolics and antioxidant activities of bark and leaf extracts of *Goniothalamus velutinus* (Airy Shaw) from Brunei Darussalam. 27 (3), 224-232. ISSN 1018-3647. https://doi.org/10.1016/j.jksus.2015.02.003.

Fagbemi, K.O., Aina, D.A., Adeoye-Isijola, M.O., Naidoo, K.K., Coopoosamy, R.M. and Olajuyigbe, O.O. 2022. Bioactive compounds, antibacterial and antioxidant activities of methanol extract of *Tamarindus indica* Linn. Scientific Reports. 10.1038/s41598-022-13716-x.

Fossati, E., Narcross, L., Ekins, A., Falgueyret, J.P., Martin, V.J.J. 2015. Synthesis of Morphinan Alkaloids in *Saccharomyces cerevisiae*. PLoS ONE 10(4): e0124459. doi:10.1371/journal.pone.0124459.

Galm, U. and Shen, B. 2007. Natural product drug discovery: The times have never been better. Chem. Biol 2007; 14:1098–1104. doi: 10.1016/j.chembiol.2007.10.004

Ganapathy, A.S., Thirukannamangai, K., Swetha, P.M.I., Krishnaswamy, B. and Shunmugiah, K.P. 2018. 5-hydroxymethyl-2-furaldehyde from marine bacterium *Bacillus subtilis* inhibits biofilm and virulence of Candida albicans, Microbiological Research. 19-32. ISSN 0944-5013, https://doi.org/10.1016/j.micres.2017.11.002.

Gaudin, T., Rotureau, P., Pezron, I. and Fayet, G. 2017. Conformations of nalkyl-α/β-D-glucopyranoside surfactants: Impact on molecular properties. Comput Theor Chem., 1101:20–9.

Ghazanfar, S.A. and Fisher, M. 1998. Vegetation of the Arabian Peninsula. Kluwer Academic, Dordrecht, The Netherlands. 1998.

Hamazaki, K., Suzuki, N., Kitamura, K.I., Hattori, A. and Nagasawa, T. 2016. Cis vaccenic acid (18:1t n-7) associated with an increased incidence of hip fracture? An explanation for the calcium paradox. Essential Fatty Acids. 109:8–12. https://doi.org/10.1016/j.ejmech.2021.113516.

Harrison, R.M., Beddows, D.C.S., Jones, A.M., Calvo, A., Alves, C. and Pio, C. 2013. "An evaluation of some issues regarding the use of aethalometers to measure woodsmoke concentrations" (PDF). Atmospheric Environment. 80: 540-548. doi:10.1016/j.atmosenv.2013.08.026.

Hayat, M.M. and Uzair, M. 2019. Biological potential and GC-MS analysis of phytochemicals of Farsetia hamiltonii (Royle). Biomedical Research. 30 (4):

609-616.

Ibrahim, H.M. and Behbehani, H. 2014. Synthesis of a new class of Pyridazin-3-one and 2-amino-5-arylazopyridine derivatives and their utility in the synthesis of fused azines. Molecules. 24;19(2):2637-54. doi: 10.3390/molecules19022637. PMID: 24566327; PMCID: PMC6272007.

Ibrahim, L.F., Kawaswty, S.A., Baiumony, A.R., Shabana, M.M., ElEraky, W.I. and El-Negoumy. 2007. Chem Nat Compounds, 43 (24): 27.

Irshad, M., Mehdi, S.J., Al-Fatlawi, A.A., Zafaryab, M., Asgar, A., Irfan, A. and Man, S., M. M.A. R. 2014. Phytochemical composition of Cassia fistula fruit extracts and its anticancer activity against human cancer cell lines. J Biologically Active Prod. Nature. 2014; 4: 158-170. https://doi.org/10.1080/22311866.2014.933084.

Islam, S., Mohammed, A., Hosen, S. A., Muhammad, T., Qamar, S., Sujan, Dey., Imtiaj, H., Yuki, F., Yasuhiro, O. and Sarkar, M.A. 2022. Synthesis, antimicrobial, anticancer activities, PASS prediction, molecular docking, molecular dynamics and pharmacokinetic studies of designed methyl á-D-glucopyranoside esters. Journal of Molecular Structure. 2022; 1260: 132761, ISSN 0022-2860, https://doi.org/10.1016/j.molstruc.2022.132761.

Ismail, W.M., Amira, A.M., Nadia, M., Sokkar, A.M. and El-Fishawy. 2013. Botanical and genetic characteristics of Farsetia aegyptia Turra growing in Egypt, Bulletin of Faculty of Pharmacy, Cairo University. 51 (2): 151-165. ISSN 1110-0931. https://doi.org/10.1016/j.bfopcu.2013.04.001.

Ivaldo, I.J., Marcelo, A.D.N., Rodrigo, O.M., Alves, Anthony, D. and Robert W. 2020. Levoglucosan: a promising platform molecule?. Green Chemistry 22 (18): pp.5859-5880. ff10.1039/d0gc01490gff. ffhal-03024535.

Jawaher, A., Mohamed, D., Rami, R., Jalloul, B. 2022. Brassica Genus Seeds: A Review on Phytochemical Screening and Pharmacological Properties. Molecules, 27(18): 6008; https://doi.org/10.3390/molecules27186008.

Karthikeyan, M., Subramanian, P. and Ramalingam, S. 2019. Phytochemical analysis in economically important Ficus Benghalensis L. and Ficus Krishnae CDC using GC-MS. Int. J. Pharma. Bio. Sci., 10: 5–13.

Ki, H.K., Eunjung, M., Sun, Y.K., Sang, U.C., Jei, H.L. and Kang, R.L. 2014. 4-Methylthio-butanyl derivatives from the seeds of Raphanus sativus and their biological evaluation on anti-inflammatory and antitumor activities, Journal of Ethnopharmacology., 151: (1): 503-508,https://doi.org/10.1016/j.jep.2013.11.003.

Kim, D.Y. and Choi, B.Y.,2019. Costunolide-A Bioactive Sesquiterpene Lactone with Diverse Therapeutic Potential. Int J Mol Sci., 20(12):2926. doi: 10.3390/ijms20122926. PMID: 31208018; PMCID: PMC6627852.

Kirtikau, R. and Basu, L., 1975. Indian medicinal Plants (2nd Edition). Vol 1. Bishen Singh, Mahendra Pal, India p151.1975.

Koichi, T., Kazuhiro, T., Takayuki, S. and Yoshiaki, S. 2017. Synthesis of Amide and Ester Derivatives of Cinnamic Acid and Its Analogs: Evaluation of Their Free Radical Scavenging and Monoamine Oxidase and Cholinesterase Inhibitory Activities Chem. Pharm. Bull. 65: 1020–1027.

Kumar, V., Ahmed, D. and Verma, A. 2013. Umbelliferone â-D-galactopyranoside from Aegle marmelos (L.) corr. an ethnomedicinal plant with antidiabetic, antihyperlipidemic and antioxidative activity. BMC Complement Altern Med. 2013. 13: 273. https://doi.org/10.1186/1472-6882-13-273.

Lee, S.H., Young-Chang, C. and Jae, S.L., 2021. Costunolide, a Sesquiterpene Lactone, Suppresses Skin Cancer via Induction of Apoptosis and Blockage of Cell Proliferation. Int. J. Mol. Sci., 22(4):2075; https://doi.org/10.3390/ijms22042075.

Madouh, T.A., 2023. The influence of induced drought stress on germination of Cenchrus ciliaris L. and Cenchrus setigerus Vahl.: implications for rangeland restoration in arid desert environment of Kuwait. Res. Ecol.. 2023; 5, 1-11. https://doi.org/10.30564/re.v5i1.5426.

Madouh, T.A. 2022. Eco-Physiological responses of native desert plant species to drought and nutritional levels: case of Kuwait. Front. Environ. Sci 2022; 10: 785517. doi: 10.3389/fenvs.2022.785517.

Madouh, T.A. and Quoreshi, A.M. 2023a. The function of arbuscular mycorrhizal fungi associated with drought stress resistance in native plants of arid desert ecosystems: A review. Diversity 15: 391. https://doi.org/10.3390/d15030391.

Madouh, T.A. and Quoreshi, A.M. 2023b. Terrestrial Habitats and Ecosystems of Kuwait. In: Suleiman, M.K. and Shahid, S.A. (eds) Terrestrial Environment and Ecosystems of Kuwait . Springer, Cham. https://doi.org/10.1007/978-3-031-46262-7_10

Ma³gorzata, K., Anna, B.B., Dziadek,M.K., Tomasz, P.,

Zbigniew, J. and Witczak, J.D. 2017. Evaluation of the Mycobactericidal Effect of Thio-functionalized Carbohydrate Derivatives. Molecules, 22(5): 812; https://doi.org/10.3390/molecules22050812.

María, T.A., Carmen, M.F., Elena, E.R., José L. and Miguel E. 2008. 106 (2): 83-84. https://doi.org/10.1016/j.tripleo.2008.04.002.

Marzouk, B., Marzouk, Z., Décor, R., Edziri, H., Haloui, E., Fenina, N. and Aouni, M. 2009. Antibacterial and anticandidal screening of Tunisian Citrullus colocynthis Schrad. from Medenine. J Ethnopharmacol. 125(2):344-9. doi: 10.1016/j.jep.2009.04.025. Epub 2009 May 3. PMID: 19397972.

Marzouk, M.M., Ahmed, E., Mona,E., Mai, M.F., Salwa, A.K., El-Sayed, S., Abdel, H., Sameh, S. 2020. Chemical Profiling of *Farsetia aegyptia* Turra and *Farsetia longisiliqua* Decne. and their Chemosystematic Significance R. Hussein1Trop J Nat Prod Res., 4(11):953-960.

Mishra, S., Naveen, P., Pragya, C., Chandra, P. S., Sajiya, P., Ravi, P., Anuradha, S., Atul, G. and Susanta, K., 2021. Design, synthesis, *in vitro* and *in vivo* biological evaluation of pyranone-piperazine analogs as potent antileishmanial agents, European Journal of Medicinal Chemistry 2021. 221:113516, ISSN 0223-5234.

Mohammed, A., Al-Omair, M., Khalaf, A.H., Touny, H., Elsawy, M.M. and Saleh, S.,2019. Antimicrobial activities of mesoporous nickel phosphate synthesized with low-temperature method, Microchemical Journal 2019; 145: 113-118, ISSN 0026-265X,https://doi.org/10.1016/j.microc.2018.10.028.

Muthulakshmi, A., Jothibai, M. R. and Mohan, V.R. 2012. GC-MS Analysis of Bioactive Components of *Feronia elephantum Correa* (Rutaceae). Journal of Applied Pharmaceutical Science 2012; 02 (02): 69-74.

Odnoshivkina, U.G., Kuznetsova, E.A. and Petrov, A.M. 2022. 25-Hydroxycholesterol as a Signaling Molecule of the Nervous System. Biochemistry Moscow. 87: 524–537. https://doi.org/10.1134/S0006297922060049.

Olena, R., Barbro, E., Maximilian, P., Erik, B., Anders, B., Anders, S., Henrik, A. and Madeleine, R. 2011. The Antibacterial Activity of GA3 is influenced by Ligand Complexation as Well as the Bacterial Carbon Source. Antimicrobial agents and chemotherapy. 5568–5580 doi:10.1128/AAC.00386-11.

Palombo, E.A. 2006. Phytochemicals from traditional medicinal plants used in the treatment of diarrhoea: Modes of action and effects on intestinal function. Phytother. Res., 20: 717–724.

Pandey, K.B. and Rizvi, S.I. 2009. Plant polyphenols as dietary antioxidants in human health and disease.Oxidative Medicine and Cellular Longevity. 2: 270–278.

Pandey, R. 2015. Mineral Nutrition of Plants. In: Plant Biology and Biotechnology (edited by B. Bahadur, R.M. Venkat, L. Sahi-jram and K. Krishnamurthy). Pp. 499–538. New Delhi: Springer. 2015. for the Indian population. Food Science and Technology. 57(1): 525-532. https://doi.org/10.1111/ijfs.15414.

Phutdhawong, W., Chuenchid, A., Taechowisan, T., Sirirak, J. and Phutdhawong, W.S. 2021. Synthesis and Biological Activity Evaluation of Coumarin-3-Carboxamide Derivatives Molecules. 16:26(6):1653. doi: 10.3390/molecules26061653. PMID: 33809679; PMCID: PMC8002271.

Prado, M., Silva, E.J., Duque, T.M., Zaia, A.A., Ferraz, C.C., Almeida, J.F. and Gomes, B.P. 2015. Antimicrobial and cytotoxic effects of phosphoric acid solution compared to other root canal irrigants. J Appl Oral Sci. 2015; 23(2):158-63. doi: 10.1590/1678-775720130691. PMID: 26018307; PMCID: PMC4428460.

Praveena, P.E., Periasamy, S., Kumar, A. and Singh, N. Cytokine profiles, apoptosis and pathology of experimental Pasteurella multocida serotype A1 infection in mice. Res. Vet. Sci 2010; 89: 332–339.

Qadir, A., Aqil, M., Ali, A., Ahmad, F.J., Ahmad, S., Arif, M. and Khan, N. 2020. GC-MS analysis of the methanolic extracts of Smilax china and Salix alba and their antioxidant activity. Turk J Chem., 44(2):352-363. doi: 10.3906/kim-1907-5. PMID: 33488162; PMCID: PMC7671229.

Samec, D. and Salopek-Sondi, B. 2019. Cruciferous (Brassicaceae) Vegetables. 10.1016/B978-0-12-812491-8.00027-8.

Sarvan, K. 2021. Plant secondary metabolites (PSMs) of Brassicaceae and their role in plant defense against insect herbivores – A review. Journal of Applied and Natural Science. 2021; 9 (1): 508 - 519 (2017).

Schepetkin, I., Plotnikov, M., Khlebnikov, A., Plotnikova, T. and Quinn, M. 2021. Oximes: Novel Therapeutics with Anticancer and Anti-Inflammatory Potential. Biomolecules.11: 777.

Semwal, P., Painuli, S., Badoni, H. and Bacheti, R.K. 2018. Screening of phytoconstituents and

antibacterial activity of leaves and bark of *Quercus leucotrichophora* A. Camus from Uttarakhand Himalaya. Clinical Phytoscience. 4(1). https://doi.org/ 10.1186/s40816-018-0090-y.

Shah, R. and Verma, P.K. 2018. Therapeutic importance of synthetic thiophene. Chem Cent J 2018; 19:12(1):137. doi: 10.1186/s13065-018-0511-5.

Silva, N.C.C. 2010. Fernandes A. Biological property of medicinal plants: a review of their antimicrobial activity. J Venom Anim Toxins Incl Trop Dis. 16: 402-13.

Singh, P., Kesharwani, R.K. and Keservani, R.K. 2017. Protein, carbohydrates, and fats. In: Energy metabolism. Sustained energy for enhanced human functions and activity (edited by D. Bagchi). Pp.103–115. New York, USA: Academic Press.

Soengas, P., Sotelo, T., Velasco, P. and Elena, M. 2011. Antioxidant properties of Brassica 564 Vegetables. Functional Plant Science and Biotechnology, 5(2): 43–55.

Soundararajan, P. and Kim, J. 2018. Anti-Carcinogenic Glucosinolates in Cruciferous Vegetables and Their Antagonistic Effects on Prevention of Cancers. Molecules, 23: 2983. 10.3390/molecules23112983.

Suleiman, M.K., Bhat, N.R., Abdal, M.S., Zaman, S. and Jacob, S. 2010. Propagation studies in *Farsetia aegyptia* Turra. International Journal of Biodiversity and Conservation, 2:30"32.

Tanila, B.H., Davide, M., Girolamo, C., Mario, D.A., Louis, S.H., John, R., Traynor, A.C., Helmut, S. and Mariana, S. 2014. Exploring Pharmacological Activities and Signaling of Morphinans Substituted in Position as Potent Agonists Interacting with the ì Opioid Receptor Molecular Pain. Volume 10, January-December https://doi.org/10.1186/1744-8069-10-4.

Temitayo, I., Subair, S., Oluwole, B., Akawa, O. S., Soremekun, F., Olotu, A. and Mahmoud E. S. Soliman. 2013. [(2,4-Dichlorophenyl)methyl]-7-hydroxy-1,2,3,4-tetrahydro-8H-pyrido[1,2-a]pyrazin-8-one as COMT Inhibitor in the Treatment of Parkinson's Disease: A Molecular Dynamic Simulation Approach. 2021; 18(9).https://doi.org/ 10.1002/cbdv.202100204.

Therese, P., Katarina, C., Jennifer, H., Rolf, M. and Andreas, K. 2020. Synthetic and Biological Studies on New Urea and Triazole Containing Cystobactamid Derivatives. Chemistry-A European Journal Chem. Eur. J. 26, 4289 - 4296. doi.org/ 10.1002/chem.201904073.

Tripathi, M.K., Mishra, A.S., Misra, A.K., Prasad, R., Modal, D. and Jakhmola, R.C. 2003.Effect of graded levels of high glucosinolate mustard (*Brassica juncea*) meal inclusion on nutrient utilization, growth performance, organ weight and carcass composition of growing rabbits. World Rabbit Sci., 11: 211-266.

Tripathi, M.K. and Mishra, A. S. 2007. Glucosinolates in animal nutrition: A review. Animal Feed Science and Technology. 132: 1–27.

Vasudevan, A.,Vijayan, D., Mandal, P., Karthe, P., Sadasivan, C. and Haridas, M. 2012. Anti-Inflammatory Property of n-Hexadecanoic Acid: Structural Evidence and Kinetic Assessment. Chemical biology & drug design 2012; 80: 434-9. 10.1111/j.1747-0285.2012.01418.x.

Wei, Q. and Zhang, Y.H. 2023. Composition and Antioxidative and Antibacterial Activities of the Essential Oil from *Farfugium japonicum*. Molecules.; 19;28(6):2774. doi: 10.3390/ molecules28062774.

Yan, C., Zheng, M., Sullivan, A.P., Shen, G., Chen, Y., Wang, S., Zhao, B., Cai, S., Desyaterik, Y., Li, X., Zhou, T., Gustafsson, Ö. and Collett, J.L. 2018. "Residential Coal Combustion as a Source of Levoglucosan in China". Environmental Science & Technology 52 (3): 16651674. Bibcode: 2018EnST...52. 1665Y. doi:10.1021/acs.est. 7b05858.PMID 29244948.

Yuan, H., Ma, Q., Ye, L. and Piao, G. 2016. The Traditional Medicine and Modern Medicine from Natural Products. 29; 21(5):559. doi: 10.3390/ molecules21050559. PMID: 27136524; PMCID: PMC6273146.

Zhao, J., Davis, L.C. and Verpoorte, R. 2005. Elicitor signal transduction leading to production of plant secondary metabolites. Biotechnol. Adv., 23:283–333.