

## Trends in Natural Products Research



الملتقى الدولي الثاني حول اللبان والنباتات الطبية

ABSTRACTS OF SECOND INTERNATIONAL MEETING ON FRANKINCENSE  
& MEDICINAL PLANTS. DHOFAR UNIVERSITY, SULTANATE OF OMAN,  
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### Comparative Investigation of Resins of *Boswellia* Species with Respect to Chemical Composition, Cytokine Regulatory Properties, And Effect on Cancer Cells

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For centuries, the frankincense oleogum resin of *Boswellia* trees has been highly valued in the traditional medicine of many cultures for its anti-inflammatory, analgesic, antibiotic and potentially antitumor effects. Intensive research at the end of the 20th century identified boswellic and lupeolic acids as pharmacologically active ingredients. The content and composition of boswellic and lupeolic acids, which belong to the class of pentacyclic triterpenoids, vary greatly among the approximately 25 known *Boswellia* species. In addition, pharmaceutical processing into therapeutic preparations greatly affects the chemical composition. Therefore, a novel, highly sensitive and accurate method has been developed that allows selective quantification of boswellic and lupeolic acids by a combination of high-performance liquid chromatography and tandem mass spectrometry (HPLC-MS/MS). The developed method that uses internal standards enables accurate and selective quantification even in complex biological matrices such as, for example, human plasma. By combining the developed analytical method with multivariate statistical techniques, specific patterns in boswellia and lupeolic acid composition were detected in 41 frankincense resin samples. These patterns allowed chemotaxonomic differentiation between different *Boswellia* species. This provides an opportunity to complement with meaningful chemical analyses the botanical classification, which is often difficult due to political, economic and geographical conditions in the growing regions. On the basis of these data, a formula has been developed that allows the analysis of just three boswellic acids to provide a key figure for the classification of frankincense oleogum resin samples. In addition, a new boswellic acid, 11-keto- $\alpha$ -boswellic acid ( $\alpha$ KBA), was characterized and detected in frankincense oleogum resin. This was the first time it was shown that the corresponding  $\alpha$  constitutional isomer exists besides 11-keto- $\beta$ -boswellic acid ( $\beta$ KBA). Due to the lack of drug approvals for frankincense oleogum resin preparations in Germany, the quality of the available products is highly variable and their effect on the end user cannot be surely assessed. The investigation of 16 frankincense preparations revealed remarkable differences in terms of active ingredient contents, with total contents ranging from 3.5 mg to 157.3 mg of boswellic and lupeolic acids per capsule. To compare the immunoregulatory properties of the frankincense resin preparations, the effect on cytokine release was studied on LPS-stimulated human whole blood samples. Preparations with a high content of boswellic and lupeolic acids were able to significantly reduce the release of the potent proinflammatory cytokines TNF- $\alpha$ , IL-6, and IL-8. In addition to the immunoregulatory effect, the potential growth regulatory effect of 40 commercial frankincense oleogum resin extracts, 16 frankincense resin preparations, and ten boswellic and

lupeolic acids was studied *in vitro* on therapy-resistant triple-negative mammary carcinoma cell lines. The studies showed significant antiproliferative properties on the cell lines MDA-MB-231, MDA-MB-453, and CAL-51. Using correlation analyses, the acetylated components acetyl-lupeolic acid (ALA), 3-O-acetyl- $\alpha$ -boswellic acid ( $\alpha$ ABA), and 3-O-acetyl- $\beta$ -boswellic acid ( $\beta$ ABA) were identified as particularly active components. Proliferation analyses under treatment with pure compounds further verified the causality of the observed correlations. To investigate the antitumor effect of frankincense resin preparations and boswellic acids *in vivo*, MDA-MB-231 cells were xenotransplanted onto the chorioallantoic membrane (CAM) of fertilized chick eggs. This approach demonstrated that frankincense resin preparations with high boswellic and lupeolic acid contents significantly inhibited tumor growth and proliferation of mammary carcinomas *in vivo* by induction of apoptosis. The same effects were obtained by treatment with the pure boswellic acid  $\beta$ ABA. Remarkably, no systemic toxicity was observed on the susceptible chick embryos under treatment with these natural products. In summary, the specific compositions of boswellic and lupeolic acids in frankincense resins are suitable for chemotaxonomic differentiation of boswellia species. Commercial frankincense resin preparations vary widely in terms of triterpenoid content as well as immunoregulatory properties. However, high-quality frankincense resin preparations can inhibit the release of proinflammatory cytokines. Moreover, frankincense resin extracts and frankincense resin preparations show antiproliferative and cytotoxic effects on treatment-resistant breast carcinoma cells *in vitro* and *in vivo*. Desirable immunoregulatory and cytotoxic properties correlate in particular with the levels of acetylated boswellic acids. Although Indian frankincense (*B. serrata*) is often used for preparations from frankincense oleogum resin, based on the present study, with respect to therapeutic efficacy, Arabian frankincense (*B. sacra*) provides a better triterpenoid composition. The strongest therapeutic effects were shown by the boswellic acid  $\beta$ ABA. Therefore,  $\beta$ ABA should be considered for standardization or normalization of frankincense oleogum resin preparations as well as for the development of potential therapeutics.



### **The Importance of Research and Development in the Technological and Scientific Enhancement of the Extraction, Separation and Bioactivities of the Endemic Plants Ingredients Including *Boswellia sacra* L. in the Regional Economic and Industrial Development.**

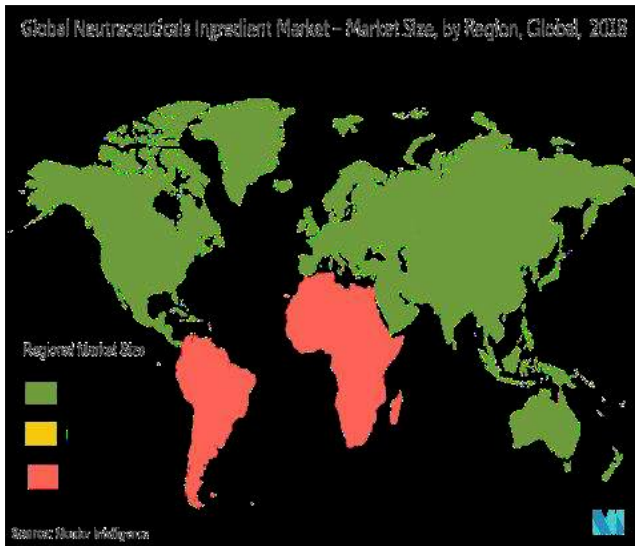
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The "Data bridge Market Research" report published in 2022 on the plant-based functional food and nutraceutical ingredients market, believes that the bioactive ingredients market can become the largest market in the world and which will play an important role in the progressive impact on the global economy taking into account climatic and environmental constraints: Bioactive natural ingredients cannot be considered as distinct chemical compounds but natural functional derivatives with high added value for various applications. For these ingredients derived from plant resources and with high added value, research focuses on how these specific bioactives can potentially respond to consumer interest in food, health, nutrition, care, environment, prevention and well-being. The global market for these ingredients in 2022 – focuses on sustainable and natural ingredients to meet the changing demand of consumers who are increasingly sensitive to the naturalness of products, these are:

- Ingredients for functional food and beverages
- Food supplement ingredients
- Personal care and cosmetic ingredients
- Bio-natural additives for animal feed
- Ingredients for pet food
- Nutrition and wellness ingredient companies



The cartography of the interest represented by ingredients at the global level, both in terms of their production, their transformation and their industrial and commercial development, shows the absence of the African continent and the Middle East, of this market of the future on which the Sultanate of Oman, has strong potential for regional and international positioning. By its geographical contrasts, its oceanic-continent, desert and tropical climate, the Sultanate of Oman is characterized by a varied range of bioclimates at the same time oceanic, desert and continental rich in a unique flora in the Arabian Peninsula and giving very amazing varieties of plants the ability to adapt to extreme climatic conditions. This variety of several thousand species (1200 species including 80 endemic, [www.oman-botanic-garden.org](http://www.oman-botanic-garden.org)) constitutes an important phylogenetic reservoir and a very marked endemism with very high potential for development. The common and endemic species, of functional interest, estimated at several thousand and of which the most representative is *Boswellia sacra* L. represent a very significant economic and industrial development potential for the territory and the development of the Sultanate. An ethnobotanical directory and the establishment of a local and regional pharmacopoeia will make it possible to identify endemic species with high potential for valorization for the development of new superior quality ingredients, through innovative transformation and separation processes creating high added value, functional validations of innovative ingredients using advanced research tools and approaches for applications in the nutrition, care, well-being and environmental sectors. This approach to promoting endemic species via research and development methods integrating ecological and sustainable transformation, identification of new natural ingredients with high added value for various applications, constitutes a real regional and international socio-economic and industrial challenge, in an approach involving researchers, developers and operators for regional and international ambitions. This conference is based on more than 30 years of experience of its author in research and functional development of plant resources in Europe and North Africa, to insist on the relevance for researchers and operators in the Sultanate of Oman to work around of a bio-green value chain combining research, industrialization and regional and international development around 80 endemic species with high potential for development through new functional ingredients.



## Effects of Frankincense on Experimentally Induced Renal Stones in Rats

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**Objectives:** Frankincense (Luban) is a resin obtained from trees of genus *Boswellia*. The south of Oman hosts *Boswellia sacra* trees known to have many social, religious and medicinal uses. The anti-inflammatory and therapeutic potential of Luban has recently attracted the interest of the scientific community. The aim is to study the efficacy of Luban water extract and its essential oils on experimentally induced renal stones in rats. **Materials and Methods:** A rat model of urolithiasis induced by trans-4-hydroxy-L-proline (HLP) was used. Wistar Kyoto rats (27 males, 27 females) were randomly distributed into nine equal groups. Treatment groups were given Uralyt-U (standard) or Luban (50, 100 and 150 mg/kg/day), starting Day 15 from HLP induction for a duration of 14 days. The prevention groups were given Luban in similar doses, starting Day 1 of HLP induction for 28 days. Several plasma biochemical and histological parameters were recorded. Data were analysed with GraphPad Software. Comparisons were performed by one-way analysis of variance (ANOVA) and the Bonferroni test. **Results:** The lithogenic effects of HLP, such as an increase in urine oxalate and cystine, an increase in plasma uric acid and an increase in kidney levels of calcium and oxalate, have all been best significantly reversed by the Luban dose of 150 mg/kg/day. The histological changes of HLP on the kidney tissue including calcium oxalate crystal formation, cystic dilatation, high degree of tubular necrosis, inflammatory changes, atrophy and fibrosis have also been ameliorated by Luban dose of 150 mg/kg/day. **Conclusion:** Luban has shown a significant improvement in the treatment and prevention of experimentally induced renal stones, particularly at a dose of 150 mg/kg/day. Further studies on the effect of Luban in other animal models and humans with urolithiasis are warranted.



## Value of Additional *Boswellia sacra* Preparation (Francoman.FO) Treatment in Cryptogenic Organizing Pneumonia (COP) – A Case Report

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Cryptogenic organizing pneumonia is a diffuse interstitial pneumonia of unknown cause, typically associated with pulmonary infiltrates of variable localization. As with secondary organizing pneumonias, there is a reversible inflammatory response and fibroblast proliferation. In addition to other immunomodulatory medications, treatment with corticosteroids is standard of care despite its known side effects. Despite recommended slow steroid reduction, recurrences may occur even during ongoing treatment and necessitate intensified immunosuppression. *Boswellia* is reported to have anti-inflammatory properties and lead to significant clinical improvement in a heavily pretreated COP patient. The aim is evaluation of the effect of additive treatment with *boswellia* to systemic corticosteroid therapy in relapsed COP. We report a 57-year-old female patient who was diagnosed with COP in a multidisciplinary team discussion based on typical clinical complaints of cough, fever, and fatigue, bipulmonary consolidations, and intraalveolar fibroblast infiltrates in transbronchial biopsies and after exclusion of other causes. Treatment with prednisolone, starting with 1mg/kg body weight, resulted in a rapid response with complete resolution of clinical symptoms and complete regression of the pulmonary infiltrates, so that the dosage was slowly reduced to prednisolone 4 mg/day. At this point, despite clinical stability, conventional radiology revealed new consolidations as a correlate of relapse and forced dose intensification of steroids. A rapid, complete regression of the infiltrates could be achieved, however, during the attempt of a new slow steroid reduction a new increase in activity of the COP with new infiltrates reoccurred twice with Prednisolone 7.5mg/day. At this point, in addition to a new increase in steroid dosage, treatment with FO 300 mg/day and transient inhalation of essential oil via diffuser was initiated. Under combined treatment, the pulmonary consolidations rapidly resolved. Combined treatment was well tolerated without any objective side effects. Steroid therapy could

be successively tapered to prednisolone 1.2 5mg per day under continued treatment with FO and sustained complete remission of disease. In addition, steroid reduction led improved control of a formally severe depression. In contrast to steroid therapy alone, supplemental administration of FO resulted in sustained disease control of COP in our patient for more than 1 year and allowed almost complete cessation of steroid medication. Our case suggests that FO may serve as an additional treatment option in patients with relapsed or refractory COP in order to taper steroid treatment. The value of FO in the treatment of patients with COP should therefore be further investigated in prospective therapeutic trials.



## **Planting of Frankincense Trees *Boswellia sacra* in Dhofar Governorate-Oman: Feasibility Study**

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The aim of the present study is to prepare a feasibility study to grow incense trees in Dhofar Governorate. The main motivation of this study is the current situation of this tree in Dhofar Governorate, where the status of this tree has become threatened due to some challenges facing the tree, such as human factors, expansion of cities and towns, indiscriminate removal of forests and trees, and overgrazing. The government of Oman has a plan to grow 1 million incense trees in 50 thousand farms. The costs, profits and other financial data are being collected and analyzed to prepare a feasibility study. The results show that growing the frankincense trees is feasible as there are many positive consequences that can be achieved in this regard. Accordingly, the study concludes that the planting of large quantities of this tree will achieve more benefits for the Omani economy, especially if the tree is cultivated in multiple and diverse locations in the governorate and in the form of reserves supervised by the relevant authorities to enhance the economic, tourism and social status of the tree in Dhofar Governorate in particular and the Sultanate in general.



## **Environmental Impact on Frankincense Trees at Wadi Dawkah Natural Park**

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Wadi Dawkah Natural Reserve of Frankincense Trees in Thumrait is considered a habitat for *Boswellia sacra* type of Frankincense trees, considered as the best type of Frankincense making lots of people and tourists from different parts of the world to come to Dhofar Governorate. A descriptive survey, observation, assessment, and analysis would be conducted by the author to conduct a comprehensive environmental impact study towards the decreasing number of trees in the Wadi Dawkah Natural reserve of Frankincense Trees. This investigation will be conducted to determine and assess the following: the decreasing population of frankincense trees, the environmental impact

due to a combination of grazing animals, changing use of land, attacks by insects, and improper harvesting leading to the decreasing number of frankincense trees, the existing management strategies that maintain frankincense sustainability, and the environment rules, norms and regulations that should be implemented by the Ministry of Heritage and Tourism and the Environment Authority. This will include assessment to identify the characteristics, trends, and categories behind Frankincense trees survival in Wadi Dawkah together with the environmental impact affecting their lives and sustainability. A management plan and procedure will include an environmental monitoring plan to keep and maintain the safety of the natural reserve. Consultation with Stakeholders and Public consultation to ensure consultation with interested parties and the public will be taking place and their views will be considered in the planning and execution of the study, as well as during the conduct of Environmental Management and Monitoring Plan. The monitoring procedures will ensure that the guidelines and recommendations stated in the environmental impacts are strictly followed. The existing laws and regulations that are applicable to the project should be reviewed along with the regulating authorities to utilize the following: survey information, environmental quality, analysis of spatial data, perception of the harvesters and traders, including participatory interviews on the harvesting practices. To conclude, the Frankincense supply chain in the Wadi Dawkah Natural Park Reserve is experiencing significant pressure from overharvesting, overgrazing, and increasing demand for resin, which has resulted in a high level of unsustainable harvesting without significantly increasing livelihood outcomes or community development. It is right time to determine the best practices for harvesting frankincense based on Oman traditional ecological knowledge and the current scientific studies and approaches. Overharvesting and overgrazing of this precious Frankincense in this study will include the approaches to ensure its sustainability and its socioeconomic environmental concerns like settlement, housing, traffic and transport, public utilities that include water supply, sanitation, solid wastes, and economic issues related to Frankincense industry. They will be assessed and compared to the current best practices and sustainability of harvesting Frankincense.



## Antimicrobial Activity of Omani Frankincense (*Boswellia sacra*) Smoke and the Size of Its Solid Particles

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Incense burning is a long, slow, incomplete combustion process that results in the generation of a continuous smoke stream with the emission of the inhalable PM<sub>10</sub> and PM<sub>2.5</sub> (particulate matter less than 10 and 2.5  $\mu\text{m}$  in aerodynamic diameter, respectively), carbon monoxide (CO), and volatile organic compounds (VOCs). The emitted fine particulate matter may pose a health risk to people inhaling them. Fumigation with frankincense is very common in Oman. However, frankincense is a medicinal plant, and thus, the overall effect and safety of fumigation with it is unclear. This study aimed to determine the size of Hojari and Sha'bi frankincense (*Boswellia sacra*) smoke solid particles and the antimicrobial activity of frankincense smoke against some air-borne microorganisms. Determination of the size of particulate matter was done using a microscopic technique. The antimicrobial activity was determined by comparing the count of bacteria and yeasts and the diameter of mold growth between test plates exposed to frankincense smoke and control plates that were not exposed to the smoke. The equivalent diameters of the smoke solid particles varied greatly with the shortest diameter being 0.75  $\mu\text{m}$  while the largest one was 2287  $\mu\text{m}$ . Thus, some solid frankincense particles were fine enough to be inhaled into the lungs. The growth of bacteria, yeasts, and molds was completely inhibited (100% inhibition) by the smoke. In conclusion, frankincense smoke possesses potent antimicrobial activity against airborne bacteria, yeasts, and molds. Although the determination of safety to fumigating with frankincense still needs more investigation, safe and efficient methods may be developed for using frankincense as an efficient sanitizer for rooms, food stores, buildings, or even open-air.



## Best Kind of Frankincense

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The best kind of frankincense (gum), according to the consensus of historians, is what is produced in Dhofar, and thus this region has become a famous market. Merchants come to it by sea and land to buy this precious commodity in order to reap the huge profits from it in the foreign markets. Since thousands of years, frankincense occupies its place, especially in the souls, and it was one of the most precious and important than gold. The research paper deals with the tree, classification of frankincense and geographical distribution in Dhofar Governorate, opening horizons for investment in the tree with all its leaves, peel, bark, fruits and flowers, in addition to the resinous gum that has therapeutic and cosmetic benefits and uses.



## Extraction And Derivatization of Medicinal Natural Products – Small Changes Can Make Large Differences

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70 % of the World population depend on phytopharmaceutical or botanical drugs, and these are commonly prepared as (hot) teas or alcoholic extractions. But also in modern pharmaceutical industry, many active ingredients for processed or even synthetic drugs are based on plant extracts, followed by purification, analysis and often derivatization. Researchers in medicinal chemistry commonly use concepts of privileged structures, skeletons, or core structures of which alterations, e.g. from a methyl to an ethyl group is a mere minor adaptation for a little better or worse fit to a target, allowing for improvements of properties, or where an extraction with boiling vs. cold water only changes extraction power, but not the principal outcome. However, this is not always the case. In my talk I will share examples, mostly from our own research, where even minor changes in the extraction or purification process of plant natural products, or minor modifications in the structure of a compound will have severe physiological consequences. One of these examples will include common work with Prof. Rashaan on the effect of cold vs. hot extracts of *Nerium oleander*, and its underlying biochemistry.



## ***In vitro* Evaluation of The Immunostimulatory Effects of Breastin on Peripheral Blood Mononuclear Cells (PBMCs)**

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Breastin was isolated from the leaves of the plant *Nerium Oleander*. It contains defined amounts of glycosides, flavonoids and polysaccharides. It showed impressive anticancer activity in human cell lines and in patient derived tumor models in 2D and 3D cultures. This activity might be attributed to cardiac glycosides mainly Oleandrin and oleandrogenin. The other components might have other effects resulting in immunomodulatory and antiviral effectiveness. Here we report on the *in vitro* immunostimulatory activity of Breastin in peripheral blood mononuclear cells (PBMCs) of 2 healthy donors. Breastin was isolated as cold extract from the leaves of the plant *Nerium Oleander*. PBMCs from 2 healthy donors were placed in medium containing Breastin 0,25 µg, 0,5 1,0 2,0 and 3, = µg/ml. The secretion of IL-1beta, IL-2, IL-6, IL-10, and TNF-alpha and Interferon-gamma was quantitatively measured by Bead Suspension Assays after 24 h of Breastin exposure. PBMC stimulations by LPS, lipopolysaccharine (1µg/ml), PMA (10ng/ml) and Ionomycin (1µg/ml) were used as positive controls. The fold changes were calculated as mean values over individual values obtained for the 3 blood donors.

- Breastin stimulated PBMCs from all 3 donors in dose dependent manner
- The extract strongly increased TNF-alpha secretion) relative to the negative vehicle control (>100-fold TNF-alpha increase at 0,5 to 3,0µg/ml and double compared to the positive control LPS
- Breastin induced PBMCs to produce IL-6 similar as to the positive control LPS and >100-fold compared to the negative vehicle control
- Breastin induced PBMCs to produce IL-1beta similar compared to the positive control LPS (lipopolysaccharide) and > 100-fold increase compared to the negative vehicle
- Breastin induced PBMCs to produce IL10 less compared to the positive control LPS (lipopolysaccharide) and markedly higher compared to the negative vehicle
- No stimulatory effects were seen for IL-2 and Interferon-gamma.

Monocytes are the main source of the cytokines TNF-alpha, IL-6 IL-1beta, and IL-8. The strong induction of these cytokines demonstrates that Breastin activates monocytes. T cells are activated by IL-2 and IL-6. The increased IL-6 levels suggest that Breastin also activates T cells. Since all measured cytokines are, to some extent, also secreted by other immune cells, it is possible that these latter cells are also activated by Breastin. Monocytes are infiltrating into tissues, where they differentiate into phagocytic macrophages providing a first line of defence against infections. They engulf pathogens and destroy them in intracellular vesicles. They are also able to activate bactericidal mechanisms in the body which finally lead to pathogen destruction. Macrophages also present antigens to T cells and can activate them. T cells are important players in antiviral and antitumoral immune responses. The levels of cytokines produced by Breastin should be biologically relevant in the human body. Other immune stimulating compounds which were also tested at Oncotest showed similar levels of cytokine release and they were already approved by the FDA e.g. for the concomitant intralesional therapy of cancer together with conventional therapies.





## Breastin A Natural Product from *Nerium Oleander* Shows *In Vitro* Immunostimulatory Effects on Peripheral Blood Mononuclear Cells (PBMCS)

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Breastin was isolated as cold extract from the leaves of the plant *Nerium Oleander*. It contains defined amounts of glycosides, flavonoids and polysaccharides. It showed impressive anticancer activity in human cell lines and in patient derived tumor models in 2D and 3D testing experiments. This activity might be attributed to cardiac glycosides main Oleandrin and oleandrigenin. The other components might have other effects resulting in immunomodulatory and antiviral effectiveness. We investigated potential immunostimulatory activities of Breastin on peripheral blood mononuclear cells (PBMCS) of healthy donors. Breastin was isolated as cold extract from the leaves of the plant *Nerium Oleander*. It contains defined amounts of glycosides, flavonoids and polysaccharides. *In-vitro* activity was determined in 63 human tumor cell lines in a monolayer assay. 4 to 10.000 cells were seeded in 96 well plates; one day later Breastin was added at 5 concentrations and incubated with the cells for 4 days. The read-out was propidium iodide-based fluorescence. In a 3D assay Breastin was tested in the clonogenic assay in 70 established human PDX as well as in bone-marrow of 3 healthy donors. Based on IC50 and IC70 values tumor selectivity was analyzed. In the Compare Analysis the IC50 and IC70 pattern of Breastin was compared with the corresponding patterns of 180 known substances using Spearman Correlations. *In-vivo* studies were carried out in subcutaneously growing tumor models. Breastin It was the most potent and selective preparation out of a series of 36 extracts that were obtained with different extraction procedures. It showed a dose-dependent antitumor activity, the mean IC50 and IC70 were 1.1 and 2.7 µg/ml, respectively. 31 / 63 cell lines investigated showed IC50 < 1.14 µg/ml. Breastin had a higher potency than several anticancer agents used in the clinic, e.g. Cisplatin, 5-Fluoruracil and Cyclophosphamide. The highest activity was seen in individual CNS, NSC lung cancer cell, prostate, and pancreas cell lines. In systematic combination studies Breastin increased the effect of the tubulin binders Paclitaxel, and Docetaxel in 4/6 cell lines, the alkylating agents Cyclophamide and Mitomycin-C in 3/6 cell lines, and Adriamycin and Alimta in 2/6 cell lines. In the 3D clonogenic assay Breastin was effective in glioblastomas, prostate, and large cell lung cancers as well as in melanomas and pleura mesotheliomas. *In vivo* Breastin was active in the mammary cancer MAXF 401 and the lung cancer LXFA 737 (T/C values 24 and 42 % of the controls). A marked synergism was observed in combination with Taxol effecting complete remission. Analyses of predictive biomarkers are ongoing. In former studies *in-vivo* activity was observed in the murine models B16 melanoma and the Lewis-Lung-carcinoma whereas the leukaemia's L1210 and P388 were resistant. The testings of 36 extracts from *Nerium Oleander* identified the cold extract Breastin as most promising anticancer agent with selective *in-vitro* activity found in CNS, NSC lung cancers as well as in prostate and pancreatic models. Moreover, in combination studies Breastin showed synergism with several cytotoxic agents. *In-vivo* a marked synergism was seen with Taxol in a breast cancer model.



## **Molecular Modes of Action of an Aqueous *Nerium oleander* Extract in Cancer Cells *in vitro* and *in vivo***

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Cancer drug resistance remains a major obstacle in clinical oncology. As most anticancer drugs are of natural origin, we investigated the anticancer potential of a standardized cold-water leaf extract from *Nerium oleander* L., termed Breastin. The phytochemical characterization by nuclear magnetic resonance spectroscopy (NMR) and low- and high-resolution mass spectrometry revealed several monoglycosidic cardenolides as major constituents (adynerin, neritaloside, odorside A, odorside H, oleandrin, and vanderoside). Breastin inhibited the growth of 14 cell lines from hematopoietic tumors and 5 of 6 carcinomas. Remarkably, the cellular responsiveness of odorside H and neritaloside was not correlated with all other classical drug resistance mechanisms, i.e., ATP-binding cassette transporters (ABCB1, ABCB5, ABCC1, ABCG2), oncogenes (EGFR, RAS), tumor suppressors (TP53, WT1), and others (GSTP1, HSP90, proliferation rate), in 59 tumor cell lines of the National Cancer Institute (NCI, USA), indicating that Breastin may indeed bypass drug resistance. COMPARE analyses with 153 anticancer agents in 74 tumor cell lines of the Oncotest panel revealed frequent correlations of Breastin with mitosis-inhibiting drugs. Using tubulin-GFP-transfected U2OS cells and confocal microscopy, it was found that the microtubule-disturbing effect of Breastin was comparable to that of the tubulin-depolymerizing drug paclitaxel. This result was verified by a tubulin polymerization assay *in vitro* and molecular docking *in silico*. Proteome profiling of 3171 proteins in the NCI panel revealed protein subsets whose expression significantly correlated with cellular responsiveness to odorside H and neritaloside, indicating that protein expression profiles can be identified to predict the sensitivity or resistance of tumor cells to Breastin constituents. Breastin moderately inhibited breast cancer xenograft tumors *in vivo*. Remarkably, in contrast to what was observed with paclitaxel monotherapy, the combination of paclitaxel and Breastin prevented tumor relapse, indicating Breastin's potential for drug combination regimens.



## ***In Vivo* Acute, Subacute and Gene Toxicity of Breastin a Natural Product from *Nerium Oleander* Leaves**

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Breastin is a patented cold extract obtained from the leaves of the plant *Nerium oleander*. It contains defined amounts of glycosides such as (adynerin, neritaloside, odorside A, odorside H, oleandrin, and vanderoside), flavonoids and polysaccharides. Breastin inhibits cancer *in vitro* and *in vivo* in hematopoietic cell lines (multiple myeloma, leukemia) and epidermal cell lines (diverse carcinomas). Phytochemical profiling revealed the monoglycosidic cardenolides adynerin, neritaloside, odorside A, odorside H, oleandrin, and vanderoside as major bioactive secondary metabolites of Breastin. Major molecular mechanisms of drug resistance were not

correlated with the activity of odoroside H and neritaloside. Although, *N. oleander* is a toxic plant, yet, it must be prematurely ignored because of its toxicity, especially since *in vivo* experiments and preliminary clinical trials demonstrated tolerable side effects and acceptable safety profiles. The acute oral acute toxicity study was performed as per OECD Guidelines for the Testing of Chemicals (Test No. 425). The LD50 value of Breastin formulation was calculated and found to be 195mg/kg body weight in mice and classified as Category-4 based on Globally Harmonized Classification System (GHS) for Chemical Substances and Mixtures. In addition, 28 day repeated oral toxicity study was performed to determine the potential of Breastin formulation to produce toxicity when administered through oral route at doses of LD (5mg/kg), MD (20mg/kg), HD (80mg/kg) /day in male and female C57 mice in the tested condition. Mortality, body weight changes, clinical signs, feed intake, hematology, electrolytes, clinical biochemistry, organ weights, gross and histopathology were carried out. There was no death in the control and low dose groups. However, death was observed in MD (2 animals), HD (3 animals), and SHD (4 animals). Since those animals were putrefied and unable to collect the organs for histopathological examinations. However, remaining all survived animals showed no treatment related gross pathological changes and histopathological findings in Breastin Formulation administered mice when compared to the control animals. There were significant increase total cholesterol and triglycerides levels in the mid, and high dose groups when compared to the control animals. The haematological, and electrolytes values were within the clinical range in both vehicle and Br1 Formulation treated animals. There were dose related toxicity and reversibility or delayed occurrence were observed in satellite group (SHD 80mg/kg) during its recovery period. Under the tested conditions, Breastin Formulation was found to be well tolerated up to 5mg/kg/day when administered through oral route for a period of 28 days in male and female mice. Hence, No-Observed-Adverse-Effect-Level (NOAEL) is concluded to be  $\leq 5$ mg/kg/day. In addition, micronucleus test was conducted in accordance with OECD test guideline 423 with minor modifications. Ninety-four Swiss Albino mice (47male and 47 female) were used for the study. Breastin administration did not induce micronuclei in the bone marrow cells of mice compared to the control mice. Positive control group exhibited an increase in the frequency of micro nucleated immature erythrocytes compared with that of control group. Therefore, Breastin is considered “non-clastogenic” at 100 mg/kg body weight in this micro nucleus assay under the tested experimental conditions



## Nutritional Composition of the Seaweed “*Hypnea Bryoides*” And Characteristics of its Organic Solvent Extracts

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This study aimed to determine the proximate composition of the species *Hypnea bryoides* (*H. bryoides*), minerals content, extract its organic solvent soluble compounds and investigate their polyphenols contents (TPC), flavonoids content (TFC), tannins content (TTC) and antibacterial activity. The non-water-soluble molecules were extracted using five different organic solvents sequentially (Hexane, DCM, ethyl acetate, acetone and methanol). The structural characteristics of the organic solvent extracts was studied by FTIR-ATR. The finding of this study showed that the carbohydrates ( $67.57 \pm 0.00$  %) were the most abundant components in *H. bryoides*, followed by protein ( $19.48 \pm 0.07$  %), and the lipid content was found the lowest ( $1.01 \pm 0.07$  %). The ash content was  $11.87 \pm 0.05$  %, and the main essential minerals found in the sample were Na, K, Ca, P, Fe, where the Na was detected with the highest concentration ( $30.19 \pm 0.43$  mg/g). Furthermore, no heavy metals were detected in the sample. The methanolic extract exhibited the highest TPC, TFC and TTC contents ( $141.3 \pm 0.59$ ,  $115.11 \pm 3.25$  and  $36.77 \pm 1.05$  mg/g, respectively) among the five fractions whereas no antibacterial activity was recorded in

any of the extracts against the cultured bacteria (*Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 25923, *Pseudomonas aeruginosa* ATCC 27853 and *Klebsiella pneumoniae* ATCC 1706). The total TPC, TFC and TTC of *H. bryoides* were found very high compared to other seaweeds.



## Antibacterial Activities of Organic Solvent Extracts from Four Omani Seaweeds

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Seaweeds or macroalgae are non-flowering plants, photosynthetic and non-vascular plants with around 12,000 species identified worldwide. They are divided into three main groups depending on natural colours or pigments, the Phaeophyta (brown algae), the Rhodophyta (red algae) and Chlorophyta (green algae). Two red seaweeds species (*Melanothamnus somalensis* & *Gelidium omanense*) and two brown seaweeds species (*Jolyana laminarioides* & *Nizamuddinina zanardinii*) were collected in September 2021 from Sadh (Dhofar governorate, Oman). Five organic solvents were used sequentially to achieve extraction. The solvents were applied in the following order: hexane, dichloromethane, ethyl acetate, acetone and methanol. Antibacterial activities of their organic solvent extracts were screened against bacterial strains of *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 25923), *Pseudomonas aeruginosa* (ATCC 27853) and *Klebsiella pneumoniae* (ATCC 1706), and fungi strain *Candida albicans*. Methanol extract of *Nizamuddinina zanardinii* showed the highest inhibition zone and colony forming units. Methanol extract was further fractionated, and the active fraction was identified. Furthermore, time depended- assay and dose depended assay were done for the active fraction. Stock concentration showed the highest activity against antibacterial activities and 3h incubation was the optimal time. Inactivated bacteria were examined by SEM and TEM to confirm efficacy of the extract. In conclusion, methanol extract of *Nizamuddinina zanardinii* has good efficiency against pathogenic bacteria and fungus.



## *Boswellia* Extract Effectiveness in Traumatic Brain Injury

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Traumatic brain injury (TBI) induces secondary injury mechanisms, including dynamic interplay between ischaemic, neuroinflammatory and neurotoxic processes. Boswellic acid (BA), the active pentacyclic triterpenic acid component present in gum resin of *Boswellia* species (such as *B. serrata* and *B. carterii*) is emerging as powerful compound endowed with significant pharmacological potential, such as anti-inflammatory, anti-oxidant, and anti-excitotoxic effects. These properties may have potential therapeutic implications in neurological disorders. Notably, BA-induced neuroprotection is proposed to be associated with the ability to reduce neurotoxic aggregates, decrease oxidative stress, and improve cognitive dysfunction. Here, we investigated for the first time the beneficial effects of *Boswellia* extract (BSE) in a mouse model of traumatic brain injury. BSE, at the dose of 500 mg/kg was able to reduce histological alteration as well as inflammation and lipid peroxidation and ameliorating behavioral alteration such as anxiety and depression. Our data may open a window for developing new therapeutic strategies to limit neuroinflammation event associated with TBI.



### ***Boswellia sacra* Flueck. Oleoresins from the Dhofar Region of Oman Inhibit Bacterial Growth and Potentiate the Effects of Conventional Antibiotics**

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The development of multiple antibiotic-resistant bacterial strains in recent years has highlighted the need to develop new antibiotic therapies. The rising incidence of MDR and TDR resistant bacterial pathogens is particularly concerning, as there are now no effective treatments for some infections. Conventional antibiotic discovery methods are unlikely to provide effective new antibiotics in the future. This need has directed antibiotic discovery research towards traditional medicines, and towards combinational therapies. *Boswellia sacra* oleoresin (frankincense) has potential for the development of new therapeutics. Frankincense has been used as an antibacterial agent (both alone and in combination with other components) in traditional Arabian and Asian healing systems for over 1000 years. However, despite its well-documented uses, *B. sacra* has not yet been rigorously tested against many bacterial pathogens. Furthermore, *B. sacra* extracts have only been tested alone against bacterial pathogens, and they are yet to be evaluated for their ability to potentiate other antimicrobial components. Solvent extracts were prepared from *Boswellia sacra* oleoresins obtained from three regions near Salalah, Oman and tested against a panel of bacteria and antimicrobial activity was quantified by MIC determination. Additionally, antibacterial activity was evaluated in combination with conventional antibiotics and the class of interaction was determined by  $\Sigma$ FIC analysis. For synergistic combinations, isobologram analysis was used to determine optimal ratios. Toxicity was evaluated using ALA and HDF cell viability bioassays and GC-MS headspace was used to analyse the phytochemical composition of the volatile components of the extracts. Interestingly, methanolic extracts prepared using Najdi oleoresin were more potent than Sahli and Houjari oleoresin extracts. Several combinations of extracts and conventional antibiotics were substantially more effective than either component alone, with 38 synergistic and 166 additive combinations detected. Notably, approximately half of the synergistic interactions occurred in combinations containing tetracycline, indicating the extract components may block tetracycline resistance efflux pumps, thereby repurposing tetracycline in otherwise resistant strains. All *B. sacra* extracts were non-toxic in the ALA and HDF cell viability assays, indicating their safety for therapeutic use. GC-MS headspace analysis of the *B. sacra* extracts identified multiple monoterpenoids, with  $\alpha$ -pinene being particularly abundant.



## Antidiabetic and Antioxidant Properties of *Boswellia sacra* Oleogum in Streptozotocin-induced Diabetic Rats

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Diabetes mellitus is a severe chronic disease with a high risk of serious complications. The edible *Boswellia sacra* (*B. sacra*) oleogum resin is widely used in traditional Arab, Chinese, African, and Ayurvedic medicine to treat a variety of clinical disorders. This study aimed to explore the potential therapeutic effects of several *B. sacra* oleogum resin extracts on streptozotocin (STZ)-induced hyperglycaemia in rats. Furthermore, the anti-inflammatory and antioxidant activities of these extracts were investigated. Hyperglycaemic rats are either treated with 200 or 400 mg/kg/day of different *B. sacra* extracts (ethanol, methanol, hydrodistilled, ethyl acetate, and acetone extracts) or metformin (reference drug; 250 mg/kg body weight per day) for 29 days. Body weights and blood glucose were measured before the initiation and at 7, 11, 16, 22, and 29 days after oral treatment. Furthermore, the oral glucose tolerance test (OGTT) was measured. At the end of the experiment, the rats were sacrificed and blood samples were collected for the measurement of cytokines (interleukin (IL-)2 and IL-8), reduced glutathione (GSH), superoxide dismutase (SOD), and serum insulin. The pancreas and liver tissues were rapidly excised, washed, fixed, and kept in 10 % formalin buffer for histological examination. The ethanolic extract of *B. sacra* displayed the highest concentration (391.52 mg/g) of total pentacyclic triterpenic acid (PTA) content when compared to the other extracts. The lower dose of *B. sacra* ethanol extract, 200 mg/kg/day, is more effective than the higher dose, 400 mg/kg/day, in lowering blood glucose levels. Diabetic rats treated with ethanol extract (200 mg/kg) fared no better than control rats in an oral glucose test (at 180 minutes) and even outperformed those given with the reference medication metformin. Furthermore, diabetic rats administered ethanol extract (200 mg/kg) or metformin gained weight. This was associated with a significant decrease in serum IL-2 and IL-8 levels, a reduction in oxidative stress as evidenced by a significant ( $p < 0.05$ ) increase in SOD and GSH compared to the diabetic untreated group, and a significant ( $p < 0.05$ ) increase in serum insulin levels compared to normal plasma rat levels. These findings, which were corroborated by histochemical assays, indicated that the ethanol extract of *B. sacra* greatly enhanced the cellular architecture of pancreatic and liver cells. The present study reports, for the first time to our knowledge, that the ethanol extract of *B. sacra* oleogum resin, which contains a high proportion of acetyl- $\beta$ -boswellic acid ( $\beta$ -ABA) and acetyl-11-keto- $\beta$ -boswellic acid (AKBA), possesses antihyperglycemic, anti-inflammatory, and antioxidant properties. It also protects the pancreas from oxidative damage and recovers hepatic cells in STZ-induced diabetic rats. Thus, the findings of the current study provide a scientific basis for the use of *B. sacra* in the management of diabetes and its complications. More research into these extracts' metabolic profiles is required to pinpoint the precise mechanism of action of the ethanol extract.



## Treatment of Glioblastoma (GBM) with a High Dose and Long-duration *Boswellia sacra* Preparation: A Case Report

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Glioblastoma is the most aggressive type of brain tumor. Current therapeutic strategies involve Surgery, Temozolomid (TMZ) and radiation therapy (RT). Despite maximum treatment, the cancer almost recurs. The typical duration of survival following diagnosis is 12–15 months, with less than 3 % of people surviving longer than five years. A dose of more than 4.1 mg/day of dexamethasone decreased the mean overall survival (OS) to 4.8 months versus 11 months mean OS in those who received less than 4.1mg/day. Therefore, decreasing glucocorticoid used in those with GBM may not only serve to enhance immune response and increase efficacy of standard therapies but also increase overall survival. Recent study showed *Boswellia* significantly increased the anticancer activities of TMZ and Afatinib We report the case of a patient with GBM treated with standard treatment plus high dose and long term *Boswellia sacra* preparation (FrankOman). A 43-year-old university professor. He started showing trouble in speaking, understanding words, reading, and writing and headache. The investigations done with Brain-MRI showed a brain mass in right parietal lobe, with extensive edema. On April 2017 underwent a stereotactic biopsy due to the deep location and definitive histology revealed GBM without IDH1 mutation. He has been treated with radiochemotherapy (TMZ) plus *Boswellia sacra* preparation (FrankOman). He started with 1800 mg daily, and the dose was increased after two weeks to 4000 mg till now. He used to take dexamethasone 16 mg/ day during the first weeks of treatment and the dose was adjusted later to be at the end of the radiotherapy 1 mg twice daily. Under combined treatment radiotherapy. TMZ and a high dose FrankOman, the rest GBM was disappeared. Combined treatment was well tolerated without any objective side effects and the patient in the last five years ago in a complete remission. He resumed his work at the university. Steroid therapy could be successively tapered and stopped rapidly. The results so far achieved are promising and in accordance with result of S. Kriste 2 with no gastrointestinal side effects with high dose and long-term treatment with FrankOman preparation. Our case suggests that *Boswellia* may serve as an additional treatment to taper steroid treatment. The value of a long- term duration with a high dose of FrankOman in the treatment of patients with GBM should therefore be further investigated in prospective therapeutic trials. The results are promising and merits to be confirmed in a clinical trial study.



## Sensing Resinous Materials in the Southern Arabian Peninsula: Annotating the Data Features of a Botanical-chemical Heritage Library for the Study of Traditional Arabian Scents

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The vast study of Arabian scents chemically is currently in its nascent stages in the Arabian Peninsula. This paper outlines an analytical approach for an annotated database that characterizes biomarker features of Arabian resins including varieties of frankincense. The analysis includes identifying compounds present, list of unknown compounds identified, compound formulas, Mass Spectroscopy (MS/MS) values, Principal Component Analysis (PCA) plotting analysis, and other statistical data streams of analysis. The Heritage Library of Arabian Resins and Scents is designed to study cultural and pharmaceutical preferences for types of scents and fragrances via resinous materials sourced directly in the Arabian Peninsula, and its impact on cosmetics, perfumery, pharmaceutical, and heritage sectors in the Gulf



## Frankincense Coatings for Food Preservation

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A large portion of fruits and vegetables deteriorates before being sold or consumed. Thus, it is necessary to develop effective food preservation technology. This study evaluated the effects of chitosan and chitosan composite coatings with frankincense oil on microbial growth and strawberry quality. Chitosan is a linear polysaccharide obtained from the shells of crustaceans. Strawberries were coated with different concentrations of chitosan and frankincense oil was added to the coating. The physical and chemical properties of strawberries, such as color, texture, moisture content, pH, and total soluble solids were measured. At the end of the experiments, the total microbial and fungal counts were done. Results showed that chitosan and chitosan frankincense coatings did not significantly change the physical and chemical properties of strawberries. However, the bacteria densities were lower in chitosan frankincense coating. In conclusion, chitosan with frankincense oil could be a good choice for food preservation.



## Population Assessment of Frankincense Trees (*Boswellia sacra*) in Oman Environment Society of Oman

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Muscat, Oman (June 20, 2022) – A field team has completed a 3-month survey of frankincense (*Boswellia sacra*) in Dhofar in order to update its distribution and population status. The team comprised representatives from the Environment Society of Oman, Environment Authority, Wageningen University & Research, Fair Source Botanicals LLC, and Mendel University in Brno. The work was carried out with the support of a grant from the British Embassy, Muscat.

The frankincense tree (*Boswellia sacra*) or Ar Shajarat al-Laban in Arabic or Meġer in Jibbāli is a small, semi-deciduous tree that grows in arid areas of the Horn of Africa and southern Arabia, including Oman's Dhofar region. It is the source of frankincense resin (Luban in Arabic), which is used widely in Oman and throughout the world. There has been little research on its conservation status in Oman, but other species of *Boswellia* elsewhere in the world have been reported to be threatened and some are in decline. *Boswellia sacra* was listed in 1998 as Near Threatened on the IUCN Red List and its status is due to be updated. From January to April, 2022, the field



team conducted an assessment of frankincense in the Dhofar region. The objectives were to map populations and their distribution, assess the threats to the species, establish permanent study sites to evaluate long-term population change and ecology, engage with local stakeholders to understand community perceptions, raise awareness of and advocate for frankincense conservation, and build local capacity to survey and protect the trees. The field team found that frankincense was widely distributed in Dhofar, with large populations primarily in Jabal Qamar and Jabal Samhan. It was directly observed in 1,309 km<sup>2</sup> and is predicted to occur in 2,156 km<sup>2</sup> of the Dhofar region. Each non-permanent regeneration transects, and permanent study plots were established in multiple populations. Almost 2,000 trees were counted across all transects. Regeneration was generally good at all sites, with only two out of fifty-eight transects containing no young trees. On average, transects contained 37.5 % young trees, with the majority of transects containing 10-60 % young trees. Population structure was measured in six populations with 26 permanent transects; three to six transects per population.



## عنوان الورقة المقترحة: الديموغرافية النباتية لشجرة اللبان في محافظة ظفار محمد عكعك

وزارة التربية والتعليم - محافظة ظفار، سلطنة عُمان

من الأشجار المهمة في محافظة ظفار بسلطنة عمان. تنمو هذه الأشجار في البيئات الجافة التي لا تعتبر شجرة اللبان تتأثر بشكل رئيسي بأمطار الخريف، وتوفر مصدرا مهما للبان الذي يستخدم في الطب والعمور والتجارة منذ العصور القديمة. تواجه شجرة اللبان تحديات بيئية وبشرية تهدد استمرارها وتنوعها الجيني. تهدف هذه الدراسة إلى فحص الديموغرافية النباتية لشجرة اللبان في محافظة ظفار وتحديد العوامل المؤثرة على استدامتها.

1. تحديد توزيع وعدد أشجار اللبان في محافظة ظفار.
  2. دراسة معدلات النمو والتكاثر لشجرة اللبان.
  3. تحليل عوامل الموت والتدهور في أشجار اللبان.
  4. تحديد النسب المناسبة للأشجار الميتة والنموات الجديدة.
- سيتم استخدام عدة أساليب لجمع البيانات اللازمة للدراسة، بما في ذلك المسح الميداني، المراقبة الجغرافية، وتحليل بيانات الأقمار الصناعية ستضمن الدراسة أيضا جمع عينات من أشجار اللبان لدراسة النمو والتكاثر وتحديد المواطن المفضلة. سيتم مقارنة النتائج مع البيانات السابقة لفهم تطور السكان على مر الزمن ان وجدت راسات سابقة مشابهة، او مع صور الأقمار الصناعية السابقة لنفس المواقع من المتوقع أن تساعد نتائج هذه الدراسة في تحديد العوامل المؤثرة على استدامة شجرة اللبان في محافظة ظفار وتقديم توصيات للحفاظ على هذه الأشجار الهامة والنظم البيئي المحيط بها. ستساهم النتائج أيضا في توفير قاعدة بيانات موثوقة حول الديموغرافية النباتية لشجرة اللبان وتعزيز فهمنا للتغيرات البيئية التي تؤثر على هذه الأنواع على ضوء النتائج المتوقعة، قد تشمل التوصيات ما يلي:
1. تطوير خطط إدارة مستدامة لشجرة اللبان والمناطق المحيطة بها.
  2. تنفيذ إجراءات للحد من الأنشطة البشرية المؤثرة سلبا على أشجار اللبان والنظام البيئي المحيط بها.
  3. تعزيز الجهود البحثية والتوعية حول أهمية شجرة اللبان والتنوع البيولوجي المرتبط بها.
  4. تنفيذ برامج مراقبة وتقييم منتظمة لمتابعة الديموغرافية النباتية لشجرة اللبان والعوامل المؤثرة عليها.
- من المتوقع أن تستغرق هذه الدراسة مدة تتراوح بين 12 إلى 18 شهرا. وستتطلب موارد مادية وبشرية مختلفة، إلا ان الباحث سيقبل من التكاليف والمواقع للوصول الى النتائج قبل شهر سبتمبر 2023 م. ستساهم هذه الدراسة في تعزيز فهمنا للتحديات التي تواجه شجرة اللبان في محافظة ظفار وتطوير استراتيجيات فعالة للحفاظ على هذه الأشجار الهامة والتنوع البيولوجي المرتبط بها. ستساهم النتائج في تعزيز التعاون بين الباحثين وصناع القرار والمجتمع المحلي لضمان استدامة شجرة اللبان وتعزيز النظم البيئية والاقتصادية المترابطة في محافظة ظفار.



## Plant Demographics of the Frankincense Tree in Dhofar Governorate

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The frankincense tree (*Boswellia sacra*) is considered an important tree in Dhofar Governorate, Sultanate of Oman. These trees grow in dry environments that are not primarily affected by the autumn (*khareef*) rains, and provide an important source of frankincense, which has been used in medicine, perfumery, and trade since ancient times. The frankincense tree faces environmental and human challenges that threaten its continuity and genetic diversity. This study aims to examine the plant demographic of the frankincense tree in Dhofar Governorate and to determine the factors affecting its sustainability. The objectives are:

- Determining the distribution and number of frankincense trees in Dhofar Governorate.
- Studying the growth and reproduction rates of the frankincense tree.
- Analysis of death and deterioration factors in frankincense trees.
- Determining the appropriate proportions of dead trees and new growth.

Several methods will be used to collect the data needed for the study, including field survey, geo-observation, and satellite data analysis. The study will also include collecting samples from frankincense trees to study growth and reproduction and to determine the preferred habitats. The results will be compared with previous data to understand the evolution of the population over time if similar previous studies exist, or with previous satellite images of the same sites. The results of this study are expected to help identify the factors affecting the sustainability of the frankincense tree in the Dhofar Governorate and provide recommendations for preserving these important trees and surrounding ecosystems. The results will also provide a reliable database on the botanical demographics of the frankincense tree and enhance our understanding of environmental changes affecting this species. In light of the expected results, recommendations may include:

- Development sustainable management plans for the frankincense tree and its surrounding areas.
- Implementation of measures to reduce human activities negatively affecting frankincense trees and the surrounding ecosystem.
- Promotion research and awareness efforts on the importance of the frankincense tree and its associated biodiversity.
- Implementation of regular monitoring and evaluation programs to monitor the botanical demographics of the frankincense tree and the factors affecting it.

This study is expected to take between 12 to 18 months. It will require different material and human resources, but the researcher will reduce costs and locations to reach results before September 2023. This study will contribute to enhancing our understanding of the challenges facing the frankincense tree in Dhofar Governorate and developing effective strategies to conserve these important trees and their associated biodiversity. The results will contribute to strengthening collaboration between researchers, decision-makers and the local community to ensure the sustainability of the frankincense tree and to enhance the interconnected ecological and economic systems in Dhofar Governorate.



## ظفار: الأرض السعيدة وهبة اللبان

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لعبت تجارة اللبان في حقبات تاريخية متعاقبة دورا رئيسيا في توثيق الصلات الحضارية والإنسانية بين قارات العالم القديم وقد تكرر هذا الإقليم في المصادر الكلاسيكية نظرا لأهمية دورها التجاري حيث أشار هيردوتس إلى أرض اللبان بقول أنه توجد في الجنوب, وهذه المنطقة من أكثر المناطق اتساعا في بلاد العرب, وأن هذه المنطقة هي منطقة إنتاج اللبان. ثم جاء بعده ثيغراستوس ووصف طبيعة المنطقة التي تنمو فيها أشجار اللبان دون سواها, وأن هذه الأشجار محاطة بغابات, ومناخ الإقليم يختلف عن المناطق التي حوله.

وكل ما ذكرته المؤلفات الكلاسيكية عن أرض اللبان كان على المنطقة التي تزرع أجود أنواعه, فعندما تحدث ديودوروس الصقلي عن بلاد العرب ذكر أن أرض العرب تتميز بزراعة أشجار النباتات العطرية ويتوافر فيها العديد من أنواع الأصماغ, وكان العرب يصدرونه إلى جميع أنحاء العالم القديم, لأن حرق البخور كان من أكثر الأشياء قبولا لدى جميع المعبودات. وكان إنتاج اللبان في أكثر المناطق بعدا من تلك الأقاليم يختلف عن المناطق التي حوله.

وتطرق صاحب كتاب الطواف حول البحر الأحمر الإريثري إلى وصف أرض إقليم أرض اللبان على أنها جبلية ويصعب السير فيها وبها ضباب وسحاب داكن, كما ذكر أن هذه المنطقة موبوءة للمبحرين بجانب الساحل الخاص بها.

ويذكر علماء الإغريق والرومان أن إنتاج ظفار من اللبان ينقل بطريق البحر إلى جميع موانئ العالم ويرون بأن اللبان كان أول سلعة تجارية تعبر القارات في إطار التجارة الدولية. كما أن تجارة اللبان في عصور ما قبل الإسلام كانت تتم مع الفراعنة والآشوريين واليونانيين ولأحباش. ويذكر الدكتور العبدروس في كتاب "دراسات في الخليج العربي" بعض المعلومات عن تجارة ظفار قائلا: "تستأثر ظفار باهتمام الباحثين الغربيين لما ورد عنها في الكتب المسيحية وخاصة "الإنجيل", كما أنها تشكل الحدود الشرقية لأسرة الفطانيين". وتطرق النقوش التاريخية إلى عدد من التسميات القديمة للإقليم ومنها: أرض الإله سين (سألكن), كما عرفت في أسفار العهد القديم باسم (ميشا), وكذلك ساخاليتسوموشكا.

كانت ظفار ميناء مزدهرا وسوقا رائجة في فترة مبكرة من التاريخ؛ لإنتاجها لأثمن وأغلى المنتجات وهو اللبان, والذي كان يستخدم في المعابد وكان الطلب عليه كبيرا, وكان يتم نقله بالبحر إلى جميع أنحاء العالم شرقا وغربا وشمالا, ولهذا أقدمت مملكة "ح مير" على ضم ظفار وبالتالي تمكنت من احتكار تجارة اللبان الرائجة.

ومع القرون الأولى من العصر الإسلامي كانت تجارة ظفار على ما هي عليه من ازدهار, وخصوصا مدينة مرباط, وورد ذكرها في كتب المؤرخين القدماء, إذ ذكرها نجم الدين عمارة في كتابه "بغية المستفيد في أخبار صنعاء وزبيد" وقال أنها كانت إحدى أهم الموانئ التجارية على ساحل بحر العرب في بدايات القرن الثالث الهجري (التاسع الميلادي), كما كان النشاط التجاري قائما بين بغداد وظفار ومرباط, إذ أشار ابن الجاور وهو معاصر للقرن السابع الهجري /الثالث عشر الميلادي إلى طريق أمن يسلكه البندو في العام مرتين, يجلبون الخيل ويأخذون عوضهم العطر واليزوير جعون إلى العراق. والظاهر أن العطر يقصد بها اللبان, أما البزوز فغالبا الظن أنها المنسوجات الحريرية, إذ كانت المنسوجات الحريرية منتشرة في ظفار كما تذكر بعض المصادر, فكان أهل ظفار يستوردون الحرير والقطن والكتان ويقومون بنسجه وتصديره مرة أخرى بأثمان غالية, وكان يصدر إلى ميناء عدن وغيرها من البلاد, وكان العشور الذي يؤخذ على الثوب الظفاري في ميناء عدن مرتفعا. وهذا يدل على جودة الثوب الظفاري وكانت المنسوجات القطنية والحريرية من السلع التي كانت تصدر من ظفار.

وأسهب ابن الجاور في وصف أحوال ظفار الحبوضي (المنصورة) بقوله: "وكانت القوافل صاعدة بالخف ومنحدرة بالبضائع التي تدخل الهند".

كذلك زار الإقليم في القرن الثامن الهجري /الرابع عشر الميلادي الرحالة العربي ابن بطوطة وتحدث بتفصيل عن بعض ملامح التجارة والحياة في عاصمة البلاد, وأنهم أهل التجارة ولا عيش لهم إلا منها, تلاه الرحالة ماركو بولو وقال: "يحصل "التجار منها على أعداد كبيرة من الخيول العربية يحقق أرباحا وفيرة".

وفي مراحل لاحقة برز العديد من التجار العمانيين ممن كانوا يتاجرون باللبان فابتنوا القصور وعمروا الدور وصلوا وجالوا في البقاع والأصقاع, إنها بحق الأرض السعيدة وهبة اللبان.



## The Happy Land and The Blessing of Frankincense: Dhofar

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Frankincense trade in successive historical eras played a major role in documenting the civilizational and human ties between the continents of the ancient world, and this region has been repeated in classical sources due to its commercial importance as Herodotus mentioned that there the Land of Frankincense is located in the south and is the broadest land in the Arabian Peninsula and that this region is the region of frankincense production. After Herodotus, Theophrastus described the nature of the region in which frankincense trees grow alone, and that these trees are surrounded by forests, and the climate of the region differs from the surrounding regions. All what classical literatures spoke about the Land of Frankincense as a region that cultivates the best types of frankincense. So, when Diodorus of Sicily spoke about the Arab countries, he mentioned that the land of the Arabs is characterized by the cultivation of trees of aromatic plants and many types of gums are available from it. He also mentioned that Arabs used to export it to all parts of the ancient world because the burning of incense was one of the most acceptable things to all deities, and the production of frankincense was in the remotest parts from their lands. The author of the "*Circumnavigation of the Eritrean Red Sea*" described the Land of Frankincense as mountainous and difficult to walk in where it has much fog and dark clouds. He also mentioned to sailors along its coast that this area is infested. Greek and Roman scholars mention that the produce of frankincense from Dhofar is transported by sea to all ports of the world, and they believe that frankincense was the first commercial commodity to cross continents within the framework of international trade. The trade of frankincense was also present in pre-Islamic times as well with the Pharaohs, the Assyrians, the Greeks, and the Abyssinians. In the book "Studies in the Arabian Gulf", Dr. Al-Aidarous mentions some information about the Dhofar trade, saying: "Dhofar attracts the interest of Western researchers because of what was mentioned about it in Christian books, especially the "Bible", and it also constitutes the eastern border of the Qahtanid family.". The historical inscriptions represent a number of ancient designations for the region, including: the *Land of the god Sin (Saklin)*, and was known in the books of the Old Testament as *Misha*, as well as *Sakhalitsumoshka*. Dhofar was a thriving port and market in an early period of history. Because of its production of the most valuable and expensive product, which is frankincense, it was used in temples with great demand and was transported by sea to all parts of the world, east, west and north. That is why the Kingdom of Himyar annexed Dhofar and thus managed to monopolize the frankincense trade. With the first centuries of the Islamic era, Dhofar trade was in prosperity, especially the city of Mirbat, and it was mentioned in the books of ancient historians, as Najm al-Din Amarah wrote it in his book "*Bighat al-Mustafifi fi Akhbar Sana'a and Zabid*" (*The Desire of the Beneficiary in the News of Sana'a and Zabid*) and said "that it was one of the most important commercial ports on the coast of the Arabian Sea at the beginning of the 3rd century AH (9<sup>th</sup> century AD), as was the commercial activity between Baghdad, Dhofar and Mirbat." As Ibn al-Majwar, a contemporary of the 7th century AH / 13th century AD, referred to a safe road that the Bedouins take twice a year, bringing horses and taking perfume and Al-Bezouz from Iraq as compensation. It seems that perfume is meant by frankincense, and as for Bezouz, it is most likely the silk textiles, as silk textiles were widespread in Dhofar, as mentioned by some sources, so the people of Dhofar used to import silk, cotton, and linen, and weave it then export it again at high prices, and it was exported to the port of Aden and other countries. The tithe that was taken on the Dhofari dress in the port of Aden was quite high, indicating the high quality of Dhofari dress. Cotton and silk textiles were also among the commodities that were exported from Dhofar. Ibn Al-Majawar elaborated on describing the conditions of Dhofar Al-Habboudy (Al-Mansoura), saying: "The caravans were ascending with slippers and descending with goods entering India." Also, in the 8th century AH / 14th century AD, the Arab traveller Ibn Battuta visited the region and spoke in detail about some features of trade and life in the capital of the country, and that they are people of trade and have no livelihood or income except from trading. He was followed by the traveller Marco Polo who said: "Traders get large numbers of Arabian horses make abundant profits". In later stages, many Omani traders emerged who were trading in frankincense, so they built palaces and houses and travelled all over the world. It is truly the Happy Land and the Blessing of Frankincense.



## كيفية استخراج وجمع ونقل اللبان في محافظة ظفار

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يستخرج صمغ اللبان من اربع مناطق جغرافية وفيها تنتشر الأشجار وفيها تحدد منازل للعمال الذين يستخرج صمغ اللبان وتتبع منازل اللبان قوانين وأعراف عدة إذ أن ادارة المنزلة كانت تضم العمال والمستأجر ويسمى في عرف مجتمع اللبان "الطيبين الكبير" وكذلك الوسيط بين صاحب المنازل والمستأجر ويسمى "الطيبين الصغير" إذ يشرف على عملية جمع اللبان ويشرف على العمال ويقوم باستئجار المغارات والكهوف (مخسبين وجمعها مخاس) التي يحفظ فيها المحصول من العوامل الجوية وتجفيفه حتى يتم شحنه الى الموانئ نهاية الموسم.

كما يقوم باستئجار الحراس لحماية هذه المغارات والمدهش في نظام ادارة المنزلة أن أغلب منازل اللبان تكون مؤجرة ومالك المنازل لا يقوم باستخراج اللبان وذلك لرغبته في تولي مهمة الاشراف على عملية استخراج اللبان وجمعه كي يتولى تصريف هذه السلعة الغالية والعامل الذي يقوم بعملية التوقيع والسعف يسمى في هذه المنظومة "العوين". ويعمل على استخراج اللبان على نصف الإنتاج والنصف الاخر للتاجر حسب الشروط المتعارف عليها.

وينتج اللبان (الصمغ) من أربع مناطق جغرافية وتحتوي المنازل (أونوزل) وهي مناطق متعارف عليها حسب تقسيمات العرف التقليدي بمحافظة ظفار. والمناطق هي المنطقة الشرقية وتشمل الحوجري والحاسكي والشريط النجدي خلف سلسلة جبال محافظة ظفار من الشويمية شرقا وحتى هرويب غربا ومنطقة الشزري وتتوزع نباتاته في الجزء الغربي بين النجدي ومنطقة سقوط الأمطار الموسمية (شمال ولاية رخيوت وضلكوت وكذلك المنطقة الرابعة وهي الشعابي أو الرسمي أو السهلي وتتوزع أشجاره في السهول الساحلية المواجهة للبحر وهو أقل جودة وانتاجا نظرا لتعرضه للأمطار (الخريف والرطوبة) وينتشر في مناطق أودية أرزوق وعدونب وغورب وأرصقيتا ومودام وجدد والفزايح وكذلك النوع السهلي الثاني شمال مدينة سدح وشمال مدينة مرياط.

وهناك عدة مراحل لاستخراج اللبان حيث تضرب شجرة اللبان (التوقيع) المنتجة للصمغ في عمر لا تقل 8 إلى 10 سنوات من الانبات أو عندما تكون قادرة على تحمل ضربات التجريح، ومتوسط ما تنتجه الشجرة خلال كيلو جرام - الموسم الواحد من 20 10

الاف طن من - ويذكر الاستاذ عبد القادر الغساني (ظفار أرض اللبان) بأن محافظة ظفار تنتج ما بين 76 صمغ اللبان سنويا تقريبا، ويتم عملية تجريح الشجرة (التوقيع) لثلاث أو أربع سنوات متتالية ثم تغطي فترة راحة لتلتئم الجروح من سنة إلى سنتين. وعملية ضرب أشجار اللبان عملية حساسة جدا وتستدعي خبرة سابقة إذ أن الخطأ في الضرب يؤدي إلى عقم الشجرة وموتها وذلك عندما يصيب العامل لب أو عظم الشجرة وتسمى عملية الخطأ (خيلبيت)، ويتفاوت إنتاج الشجرة من حيث الكمية، فالشجرة التي تدر الكثير من اللبان تسمى "العفل".

ويقوم صاحب المنزلة بعد ذلك باستئجار الجمال لنقل ما استدان من التاجر مؤنة لنقلها الى المنزلة، فيحمل على ريال فرنص - الجمال من المدينة الى المنزلة لبيجار للجمال الواحد 4 2

ثم تبدأ مرحلة استخراج اللبان من المواقع المكشوفة في عملية (التوقيع) والجمع الحقيقي يكون بعد الجرح الثاني حيث تنقر (مرحلة السعف) الشجرة مرة ثالثة وهنا ينضح السائل اللبني ذو النوعية الجيدة وبعدها يبدأ عملية التجميع ومن ثم يستخرج اللبان والضربات التي تتلو "التوقيع" تسمى كل منها "السعف الاول والثاني

والثالث الخ حتى نهاية الموسم "وعمليات استخراج اللبان تمر بعدة مراحل وهي عملية التوقيع ثم مرحلة السعف الاول ثم بعد ذلك مرحلة السعف الثاني وهي مرحلة انتاج اللبان ويجمع صمغ اللبان من مواقع السعف

الثاني ويخزن في الكهوف، ثم تبدأ مرحلة السعف الثالث بعد ذلك يترك لمدة 14 يوم من السعفة ويترك لمدة 10

(- يوم وهو لبان جيد وهي عملية يتدقق منها الصمغ بكثرة ويسكن العمال وسط المنزلة وتسمى (حلون) 14

وكذلك تدر الأشجار بإنتاج الصمغ وتسمى (ديرور) وتتزامن هذه المرحلة مع شهر مايو وتستمر عمليات السعف وتتوالى السعفات كالسعف الرابع والخامس حسب الموسم ونوعية الأشجار حتى شهر أكتوبر، وفي نهاية

الموسم يتم نقل اللبان من المنازل إلى مراكز التجميع والتصدير وعند انتهاء موسم استخراج الصمغ تبدأ مرحلة (الكشم) يعطي الطيبين أوامره للعمال (العونة) بأنهاء عمليات

السعف وجمع محصول اللبان لأخر تجريح ويكون بدون سعف أو تجريح للأشجار حيث يجمعون صمغ اللبان وبذلك يكون نهاية الموسم وينقل اللبان من الكهوف والمغارات إلى التجار في المدن الساحلية بواسطة قوافل من الجمال من 10 40 جمل أو أكثر وفي بعض المناطق قد يصل إلى 100 جمل وكل جمل يحمل 6 8 جواني

محملة باللبان حسب جغرافية المنطقة

وفي النهاية تكون مرحلة (الشناقضوت) ويتم جمع اللبان من الأشجار التي سعفت آخر مرة أو يترك جمع هذا اللبان لبعض الناس الفقراء والمحتاجين وأصحاب الديون ليجمعوا منها اللبان المتبقي من الأشجار وهو يعتبر لبان متبقي من كل شجرة فص أو فصين من لبان بعد نهاية الموسم



## Method of Extraction, Collection and Transport of Frankincense in Dhofar Governorate

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Frankincense gum is extracted from four geographic regions, in which trees are spread and houses of the workers are located. The houses of frankincense follow several rules and customs wherein their management included both workers, the tenant (known as the *Big Tibeen*), and their middleman (known as the *Small Tibeen*). The Small Tibeen supervises the frankincense collection process, supervises workers, and rents caverns and caves (*Makhas*, pluralized as *Makhasis*) in which the frankincense is preserved from weather conditions and dried until it is shipped to ports at the end of the season. He also hires guards to protect these caves. What is surprising in the management system of houses of frankincense is that most of them are rented, and the owner does not extract frankincense himself because he wants to take over the task of supervising the process of extracting and collecting frankincense in order to handle the exploitation of this expensive commodity. Therefore, the workers who perform the processes of incision and collection (*Tawqee'*). The workers are called *Al-'Awain/Al-'Awanah*. They work to extract frankincense with half for production and the other half for the merchant, according to the customarily accepted conditions. Frankincense gum is produced from four geographic regions, and their houses of frankincense (*Onozel*) which are traditionally known locations according to the divisions of the traditional custom in Dhofar Governorate. These regions are the eastern region (they include Al-Hawjari, Al-Haski, and the Najdi strip behind the mountain range of Dhofar Governorate, extending from Al-Shuwaimiyah in the east to Harweb in the west), the Al-Shazari region (its trees extend from the western part of the Najdi strip and northern districts of Rakhyut and Dhalkut), and the Sha'aibi/Rasmi/Plains region (its trees extend in the coastal plains in the valleys of Arzuq, Adounb, Ghorb, Arsqeta, Modam, Jahd and Al-Fazih, as well as another plain type north of the towns of Sadah and Mirbat). The Sha'aibi frankincense is of lower quality and production due to its exposure to rain (autumn/*khareef* and humidity). There are several stages for the extraction of frankincense where the gum-producing frankincense tree is first incised at an age of at least 8 to 10 years from germination, or when it is able to withstand the blows. The average yield of one frankincense tree during one season ranges from 10-20 kilograms. Mr. Abdul Qadir Al-Ghassani in his book, *Dhofar: Land of Frankincense*, mentions that Dhofar Governorate produces between 6000-7000 tons of frankincense gum annually, and the process of cutting the tree (signature) takes place for three or four consecutive years, then a period of rest is given for the wounds to heal from one to two years. The process of incising frankincense trees is a very sensitive process and requires previous experience, as a mistake in incision leads to the sterility of the tree and its death, especially when the worker affects the core or bone of the tree. This

mistake is called *Al-Ghufl*. The owner of the frankincense house then hires camels to transfer what he borrowed from the merchant for provisions to the city at a rent per camel of 2-4 riyals. Then the stage of extracting frankincense from the abrasive sites begins in the process of *Tawqee'* and the real collection takes place after the second incision, where the tree is tapped for a third time (*Al-Saaf*). In this stage, the resinous liquid of good quality exudes, after which the collection process begins, and frankincense is extracted. Each strike or cut after *Tawqee'* has a name as "The first *Saaf*, the second *Saaf*, the third *Saaf*, etc." until the end of the season. So, the frankincense extraction processes go through several stages, which are the *Tawqee'* process, then the first *Al-Saaf*, the second *Al-Saaf*, which is the stage of frankincense production. Frankincense gum is collected from the sites of the second *Al-Saaf* stage and stored in the caves, then the third *Al-Saaf* stage begins. After that, frankincense is left for 10-14 days from *Al-Saaf*. It is a good gum, and it is a process from which the gum flows in abundance, and the workers live in the centre of the frankincense house called the *Haloun*. The frankincense trees follow a calendar (*Dairour*) based on the season and the type of trees. This last *Al-Saaf* stage starts from May and may continue into the fourth and fifth *Al-Saaf* stages based on the season and quality of the trees and may last until October. At the end of the season, frankincense is transported from the frankincense houses to collection and export centres. At the end of the gum extraction season, the stage of (*Al-Kasham*) begins. The Tibeen give orders to workers (*Al-'Awnah*; helpers) to end the operations of palm fronds and to collect the frankincense crop for the last season, without fronds or cutting of trees, where they collect frankincense gum. Thus, it will be the end of the season, and the frankincense is transported from the caves and caves to the merchants in the coastal cities. By convoys of camels from 10 40 camels or more, and in some areas, it may reach 100 camels, and each camel carries 6-8 jars loaded with frankincense, depending on the geography of the region. In the end, the stage of (*Al-Shinaqdout*). Frankincense is collected from the trees that were last cured, or the is left for poor and needy people and those with debts to collect the remaining frankincense from the trees.



## Occurrence and Risk Assessment of Mycotoxins in Aromatic and Medicinal Plants

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Aromatic and medicinal plants (AMPs), as herbal material, are subjected to contamination by various mycotoxin-producing fungi due to the lack of adopting good agricultural practices and good harvesting practices. The purpose of this study was to investigate for the first time the co-occurrence of 15 mycotoxins (four aflatoxins (AFB1, AFB2, AFG1, and AFG2), ochratoxin A (OTA), beauvericin (BEA), four enniatins (ENA, ENA1, ENB, and ENB1), zearalenone (ZEN), alternariol (AOH), tentoxin (TENT), T-2, and HT-2 toxins) in 40 samples of AMPs frequently consumed in Morocco by using liquid chromatography tandem mass spectrometry. Results showed that 90% of the analyzed samples presented at least one mycotoxin, and 52 % presented co-occurrence of them. Mycotoxins detected were: AOH (85 %), ZEN (27.5%),  $\beta$ -ZEL (22 %), AFG1 (17.5 %), TENT (17.5 %), ENB (10 %), AFG2 (7.5 %),  $\alpha$ -ZEL (5 %), ENA1 (2.5 %), and HT-2 (2.5 %). The highest observed level was for AOH, with 309 ng/g. Ten samples exceeded the recommended levels set by the European Pharmacopoeia for AF mycotoxins in plant material (4 ng/g), and three samples exceeded the maximum limits for AFs (10 ng/g) in

species established by the European Commission. More studies are still needed to assess completely the situation and to evaluate the health risks of consumers



## **Fabrication of Local Plant Extract Incorporated Natural Hydrogel for Potential Biomedical Applications**

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The objective of this research was to create economical bacterial cellulose (BC) composites with natural plant extracts that possess antimicrobial properties for potential use in biomedical applications. BC was produced using food waste in a cost-effective manner. Various plant extracts, such as pomegranate (*Punica granatum* L.) peel extract (PGPE), *Euclea schimperi*, *Aloe vera*, and Cactus, were ex situ impregnated into BC hydrogel. Multiple analytical techniques were used to characterize the plant extract impregnated composite hydrogels. It was observed that the inclusion of plant extract improved the liquid holding, mechanical, and specifically biological characteristics of BC. The antimicrobial activity of the BC composite was evaluated through minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBC), disc diffusion method, and plate count technique. The BC plant extract composites exhibited substantial antimicrobial activity against both *Staphylococcus aureus* (Gram-positive) and *Escherichia coli* (Gram-negative). The addition of aloe vera and cactus significantly enhanced the mechanical properties of BC. The results of this study suggest that incorporating naturally occurring plant extracts into BC could be a promising approach to enhance the pharmaceutical and cosmetic applications of BC.



## **Herbal And Traditional Medicines Now and Future- Pharmacovigilance Concern**

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Herbal medicines (HMs) include herbs, herbal materials, herbal preparations and finished or manufactured herbal products found in pharmaceutical dosage forms. Although there are few reliable estimates of the prevalence in use of HM, the market for HM continues to expand rapidly and has grown into a multibillion-dollar industry across the world. The influence of religious, sociocultural, and socioeconomic issues, traditional practices and belief in the use of HM is evident, particularly in Chinese, Indian and African societies. Documented use of HM in Western societies is also high. As with all medicines, HMs have been shown to have the potential to cause adverse effects which are related to a variety of causes. Furthermore, HM can affect pharmacokinetic and pharmacodynamic properties of conventional drugs and thus can cause herb–drug interactions. For these reasons, there is an increasing awareness of the need to maintain and continue to develop pharmacovigilance for HM. The use of HM must take into account their safety, efficacy, consistency and quality. The safety of these products requires strict control for the presence of adulterants, the dosage labelling, contraindications, manufacturing techniques and a list of all ingredients. In the absence of these essential elements, HM safety can be difficult to



monitor in the post-market setting. This situation can be better controlled through pharmacovigilance processes and regulatory controls. But, the current model of pharmacovigilance with all tools and methodologies was developed for conventional drugs. In these conditions, herbal and traditional medicines products for their safety, efficacy and quality, present unique challenges for pharmacovigilance.



## Tears Of Tree: The Story of Frankincense and Myrrh

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Oleo-gum resins, including frankincense and myrrh, are some of the economically and culturally valuable products derived from trees and shrubs of the genera *Boswellia* and *Commiphora*. Frankincense and Myrrh also have several local medicinal uses that could be explored and developed through research. Both frankincense and myrrh are employed in traditional medicine in several countries to treat a wide range of diseases from embalming to cancer, leprosy, bronchitis, diarrhoea, dysentery, typhoid, mouth ulcers, inflammatory conditions, viral hepatitis, gynaecological conditions, infections/wounds, coughs, and others [1-5]. We have isolated a number of natural products, namely triterpenes (including boswellic acids and myrrhanone B) and diterpenes from frankincense and myrrh, which have an interesting chemical diversity. Following the natural product-inspired diversity-oriented synthesis strategy, various derivatives of these bioactive natural products, including boswellic acid homo- and heterodimers, bis-myrrhanone B homodimers, myrrhanone B-myrrhanol B heterodimers, have been prepared with the aim of obtaining compounds with greater anticancer activity. A detailed discussion about natural and synthetic chemical diversity and their role in anticancer drug discovery will be presented.



## Quality Control of Herbal Medicine

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Herbal medicines are important options for the treatment of several illnesses. Although their therapeutic applicability has been demonstrated throughout history, several concerns about their safety and efficacy are raised regularly. Quality control of articles of botanical source, including plant materials, plant extracts, and herbal medicines, remains a challenge. Traditionally, qualitative (e.g., identification and chromatographic profile) and quantitative (e.g., content analyses) markers are applied for this purpose. Standardization of herbal formulations is essential in order to assess of quality drugs. The quality of herbal drugs is the sum of all factors which contribute directly or indirectly to the safety, effectiveness and acceptability of the product. Now a day the field of herbal drugs and formulation is very fast and there is still lot to explore on the subject of standardization of these. The herbal medicines however, suffer from lack of standardization parameters. The main limitation is the lack of standardization of raw materials, of processing methods and of the finished products, dosage formulation, and the non-existence of criteria for quality control. It is necessary to introduce measures on the regulation of herbal medicines to ensure quality, safety, and efficacy of herbal medicines by using modern suitable GMP standards.

Pharmaceutical industries should apply harsh QC (quality control) to ensure the consistency, safety, and efficacy of their herbal derived drug-preparations. QC must be performed at every stage of the production line i.e. incoming raw materials, extractions, in-process control, finished products and keeping samples. Due to the complex nature of the chemical content of herbal drugs, two approaches to QC should be taken, that is quantitative determination of the selected marker(s) compound(s), and metabolite profiling. Contamination of herbal medicines by heavy metals, pesticides, toxic metabolites, microbial toxins, pathogenic microorganisms and other foreign matter should also be evaluated. A combination of chemical profiling and multivariate analysis (MVA) is recommended as the QC tool for the botanical identification method (BIM) of herbs, extracts, herb materials, and herbal drug preparations. The limit specification range of markers used as QC tools should be described in the analytical target profile (ATP). To gain reliable results of any analysis that has been performed at any QC laboratory, the analysis method must be validated according to the newest guidance. Sample detection limit of any toxic compound(s) should be lower than its cut-off value and MPL. The reliability of any results of analysis of a QC laboratory must be evaluated by using QC-samples for each series of measurements.



## **Guidelines for Herbal Medicines and Health Supplements Registration**

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Herbal medicines and alternative medicines are subject to supervision and control by the Directorate General of Pharmacy and Drug Control, according to the Royal Decree No. 113/2020 issued on 8/11/2020. According to the World Health Organization (WHO):

- Herbal medicines are defined as finished, labelled medicinal products that contain as active ingredients aerial or underground parts of plants, or other plant material, or combinations thereof, whether in the crude state or as plant preparations. Plant material includes juices, gums, fatty oils, essential oils, and any other substances of this nature. Herbal medicines may contain excipients in addition to the active ingredients.
- Alternative medicines are defined as knowledge, skills, and practices based on the theories, beliefs, and experiences of indigenous cultures used in maintaining health, prevention, diagnosis, improvement, or treatment. It includes practices such as cupping, acupuncture, and the use of traditional medicines or a combination of them. Medicines include: Ayurvedic medicines, Homeopathic medicines and Traditional

Chinese medicines. The applicants are authorized to import, sell and market the products within the local markets after the herbal companies are registered according to the conditions and procedures stipulated in the Royal Decree, the most important of which are:

1. To be licensed by the health authorities in the country of origin, and to have a good pharmaceutical manufacturing certificate and good agricultural practice certificate.
2. To be subject to technical inspection by the health authorities on a regular basis.
3. Its medicines are marketed in the country of origin with the same composition, specifications, manufacturing and analysis methods. In order for a product be registered, the following conditions must be met, including:
  1. To pass analysis and tests to prove the quality of the drug in terms of efficacy and validity.
  2. The preservatives, coloring and diluents present in the composition of the product must be approved by the international health authorities.
  3. The percentage of alcohol in the composition of the product must be determined- if any - with justifications for the presence of this percentage.
  4. The composition of the product should be in conformity with the international pharmacopoeia.
  5. The product should be free of steroids, sex hormones, aflatoxone, pesticide residues, heavy elements, insect residues, rodents, and animal waste.

6. The product does not contain any chemically manufactured materials. After fulfilling the conditions and procedures for registering herbal companies and their products, a registration certificate is issued which is valid for 5 years.



## Newly Synthesized Benzimidazole–2–carbamate Molecules Show Suppressive Activities Against Plant Pathogenic Fungi and Oomycetes

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Most bioactive compounds are designed and synthesized by heterocyclic chemistry. Benzimidazole and its derivatives are important heterocycles that are critical subunits for pharmaceutical and biological molecules. This study was carried out to investigate the effect of 44 newly synthesized benzimidazole compounds on *Alternaria alternata*, *Rhizoctonia solani*, *Cochliobolus hawaiiensis*, *Fusarium solani*, *Lasiodiplodia pseudotheobromae* and *Pythium aphanidermatum*, which are pathogens of major crops worldwide. Well diffusion method was done using 100 µL of two different concentrations of benzimidazole compounds (1000 and 5000 ppm). The molecules designated as EBI.bB4, EBI.eB1, EBI.fB2, EBI.gB1, EBI.gB2, EBI.aB4. S, EBI.aB5.S, EBI.eB1.S and EBI.gB1.S showed suppressive effects on fungal and oomycete growth at 1000 and 5000 ppm. When these fungicides were tested against *Trichoderma harzianum*, a beneficial biocontrol fungus, the fungus was not affected. This suggests that these newly synthesized fungicides may work synergistically with *T. harzianum* in suppressing growth of the pathogenic fungi. Scanning electron microscopy showed that the fungicides resulted in malformation, bursting, swelling and hyphal tip collapse of the mycelia. The study shows that nine new fungicides show promising results in reducing growth and resulting in deformations of the mycelia of *A. alternata*, *R. solani*, *C. hawaiiensis*, *F. solani*, *L. pseudotheobromae* and *P. aphanidermatum* pathogens. The benzimidazole compounds had no effect against the biocontrol agent *T. harzianum*.



## A New Piperazine and Morpholine Derivatives; Synthesis and Anticancer Applications

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A novel series of benzoic acid N0-[2-(4-benzothiazol-2-yl-piperazin-1-yl)-acetyl]-hydrazides 6a–j were synthesized and characterized by IR, <sup>1</sup>H, <sup>13</sup>C NMR, elemental and mass spectral analyses. The in-vitro cytotoxicity and cell viability assay of the synthesized compounds 6a–j was evaluated against Dalton's lymphoma

ascites (DLA) cells. Our results showed that compound 6c with a bromo group on phenyl ring has showed promising antiproliferative efficacy. Further investigation of compound 6c on in-vivo treatment model depicts the increased tumor suppression through inhibition of angiogenesis.



#### 4th Generation Glucose Sensors Composed of MoS<sub>2</sub> Based 2D Materials

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Diabetes management presents a significant challenge, and the development of accurate glucose sensing methods remains an important but grim area. In this study, we investigated the capabilities of MoS<sub>2</sub> based 2D materials for electrochemically-active 4th generation glucose sensing in an alkaline environment. The as-prepared materials were characterized by powder X-ray diffraction (P-XRD), energy dispersive X-ray (EDX) spectroscopy, X-ray photoelectron spectra (XPS), Raman spectroscopy, scanning electron microscopy (SEM), and transmission electron microscopy (TEM). Furthermore, we evaluated the electro-catalytic properties of the fabricated electrode materials for glucose electro-oxidation in alkaline conditions using cyclic voltammetry (CV) and chronoamperometry methods. The 4<sup>th</sup> generation glucose sensors (4th GGS) made from MoS<sub>2</sub> based 2D Materials exhibited outstanding performance in glucose sensing. The MoS<sub>2</sub> based 4th GGS exhibited exceptional performance in glucose sensing. They demonstrated a wide linear range of 0.1  $\mu\text{M}$  to 2.5 mM, an ultrahigh sensitivity of 7892.10  $\mu\text{A mM}^{-1} \text{cm}^{-2}$ , and a low detection limit of 0.1  $\mu\text{M}$ . Moreover, the designed electrodes exhibited rapid response times, reaching steady-state within 0.2 seconds, and showed excellent reproducibility over 1000 cycles. The diffusion rate constant for the MoS<sub>2</sub>-based 4th GGS was determined to be 0.4 cm/s. Moreover, a real sample analysis was conducted using blood and urine samples from both non-diabetic and diabetic patients to assess the performance of the MoS<sub>2</sub>-based 4th GGS. The MoS<sub>2</sub>-based 4th GGS demonstrated impressive sensitivity in blood samples, detecting glucose levels of 13082.02  $\mu\text{A mM}^{-1} \text{cm}^{-2}$  in diabetic patient and 9336.84  $\mu\text{A mM}^{-1} \text{cm}^{-2}$  in non-diabetic person. In urine samples, the MoS<sub>2</sub>-based 4th GGS exhibited excellent sensitivity, detecting glucose levels of 10327.36  $\mu\text{A mM}^{-1} \text{cm}^{-2}$  in diabetic patient and 9785.47  $\mu\text{A mM}^{-1} \text{cm}^{-2}$  in nondiabetic person. These results highlight the potential of the MoS<sub>2</sub>-based 4th GGS for accurately detecting glucose concentrations in urine, offering possibilities for non-invasive glucose monitoring.



#### The *Termitomyces* in Oman: Taxonomy, Nutritional Value and Secondary Metabolites

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The mushroom genus *Termitomyces* belongs to family Lyophyllaceae (Basidiomycota). There are about 58 known species, all of them are edible and have unique food value attributed to their texture, flavor and nutrient content. These mushrooms form symbiotic association with termites in the subfamily Macrotermitinae. The fungus-termite symbiosis originated about 30 million years ago in the rainforests of central Africa and extended their range to almost the entire continent of Africa, Asia and some parts of Europe. The present study was designed to survey the region of Dhofar, Oman and collect *Termitomyces* specimens during the rainy monsoon season, 2022. We found several collections of *Termitomyces*, which presumably belong to one species, *Termitomyces schimperi*. The specimens are currently under accurate molecular identification using DNA barcoding and phylogenetic analyses. We are also evaluating the nutritional and biochemical properties of *Termitomyces* samples. Accurate identification of this mushroom and revealing its nutritional and biochemical properties is a step forward in our understanding and appreciation of this socially popular mushroom.



### **Isolation, Characterization and Pathogenicity of Fungal Pathogens Associated with Olive (*Olea Europaea* L) Leaf Spot and Fruit Rot in Oman**

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Olive (*Olea europaea* L) belonging to the Oleaceae family, is one of the important trees in Oman because of its religious and historical significance. Over 30 varieties of Olive trees are grown in Al-Jabal Al-Akhdhar, Oman. A number of biotic and abiotic diseases in olive have been reported worldwide. Olive tree grow in Al-Jabal Al-Akhdhar. However, little information is available on leaf spot and fruit rot diseases of olive in Oman. This study was conducted to identify the fungal pathogens associated with leaf spot and fruit rot diseases of olive in Al-Jabal Al-Akhdhar. Infected olive leaves and fruits two varieties of olive tree viz., Atm and Coratina, between July 2022 and September 2022 and fungi were isolated on potato dextrose agar medium. Total DNA was isolated from the mycelium of the fungal isolates and used in polymerase chain reaction for molecular identification using ITS4 and ITS5 primers. Pathogenicity tests were conducted under laboratory conditions by artificially inoculating healthy olive leaves and fruits and the disease severity was measured after 2-3 weeks. A total of 36 fungal isolates were recovered from diseased olive leaves and fruits. Molecular-based identification using rDNA-ITS sequences revealed that the isolates belonged to seven different fungal genera namely *Alternaria*, *Cladosporium*, *Didymella*, *Fusarium*, *Phoma*, *Cladosporium* and *Leptobacillium*. Most of the isolates belonged to the genus *Alternaria*. Inoculated leaves and fruits developed symptoms of brown to black spot in leaf and fruits. In pathogenicity tests, *A. alternata* was found to be the most aggressive, while *Leptobacillium leptobactrum* was the least aggressive. This study shows that several fungal species belonging to different genera can be found associated with leaf spot and fruit rot symptoms of olive and they are varying in their aggressiveness on olive leaves and fruits.



### **In Vitro Culture, Callus Induction and Shoot Development of the Native Strain of *Thymus Vulgaris* (Zaatar Plant) From Oman.**

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Zaatar (Thyme – *Thymus vulgaris*) is a highly appreciated aromatic medicinal plant native to Oman. It is endemic and constitutes an economically important member of the flora of hilly regions of Oman. Three major mountains were explored and the plants were obtained from Jabal Abeyad. Molecular identification of the plant was done by sequencing the rbcL gene and the sequence obtained is submitted at the GenBank of NCBI. As a part of the in vitro clonal propagation of this plant, the culture of shoot tips or nodal segments from mature plants on MS medium supplemented with different phytohormones were carried out under controlled environment. Better shoot development was obtained by using explants from the nodal segments than the shoot tips of the plant. 66.6 % response was shown when nodal segments were cultured in the modified MS Medium with activated charcoal. Callus induction was obtained from leaf explants inoculated in the modified MS medium containing 0.01 mg/L of 2,4- dichlorophenoxyacetic acid (2,4-D), 0.5 mg/L of Naphthalene acetic acid (NAA), Indole-3-acetic acid, 1.5 mg/L Benzyl amino purine (BAP), Kinetin 1mg/L with 0.25 % activated charcoal. The current work is an initial step towards conserving the Omani Zaatar plant by in vitro culture of tissues.



## **Green Synthesis of Bacterial Cellulose from Food Wastes and Developing Its Composites for Advanced Application in Medical and Electronic Fields**

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In the current study, we developed cost-effective bacterial cellulose hydrogels by utilizing locally available waste as a carbon source such as sugarcane, coconut water, leftover fruits, vegetables, and, expired juices. As pristine BC lacks antimicrobial activity, conducting and magnetic properties, and possesses limited biocompatibility and optical transparency, we developed BC composites through an ex-situ composite synthesis strategy with different polymers and nanomaterials. This led to expanding the applications as several medical and environmental products (wound dressing, facial masks, absorbing membranes and antimicrobial filters, pollutant degradation catalysts, etc.) are gained via BC composites. Besides, These BC-based composite materials find applications in the development of energy storage devices, wearable electronics, biosensors, and controlled drug delivery systems. The findings of this study provided a way for waste management that reduce economic and environmental hazards. And could be promising for medical and electronic fields.



## Fluorescence Sensing of Carboxylic Acids Using a Receptor-Based Approach

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Receptor 7, a pyrenyl-appended imidazole receptor, was designed and synthesized for the selective recognition of carboxylic acids. The binding affinity of receptor 7 toward various carboxylic acid guests, including salicylic acid, 3,4-dihydroxyphenylacetic acid, 3,4-dihydroxyhydrocinnamic acid, 3,4-dihydroxybenzoic acid, and 3,4-dihydroxy-L-phenylalanine, was investigated. Among the tested carboxylic acids, salicylic acid demonstrated the strongest binding interaction with receptor 7, resulting in a high association constant ( $K_a$ ). The fluorescence spectra of receptor 7 with the carboxylic acid guests showed enhanced monomer emissions, indicating the formation of complexes. The degree of fluorescence enhancement varied depending on the size and substituents of the carboxylic acids. Notably, 3,4-dihydroxyphenylacetic acid exhibited the highest binding affinity with receptor 7 among the phenyl carboxylic acids tested. The binding interactions between receptor 7 and the carboxylic acid guests involved hydrogen bonding and  $\pi$ - $\pi$  interactions, leading to selective complexation. This study highlights the potential of receptor 7 as a promising receptor for the selective sensing of carboxylic acids, with salicylic acid being the most effectively recognized guest. The findings contribute to the development of receptor-based approaches for the detection and analysis of carboxylic acids, with implications for various sensing and analytical applications.



## Bioinspired and Green Synthesis of Bimetallic CuO/Ag Nanoporous Materials: A Promising Approach for Vitamin D3 Detection

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In modern era, deficiency of Vitamin D3 is predominantly due to limited exposure to sunlight and UV radiation resulting from indoor lifestyles. Several studies have revealed that vitamin D3 deficiency can lead to chronic vascular inflammation, hypertension, diabetes mellitus, congestive heart failure, and left ventricular hypertrophy. Bimetallic nanoparticles (BMNPs) are verified to show excellent catalytic properties compared to their monometallic nanoparticles, attributed to their additive features and synergistic electronic interaction between the constituent metal nanoparticles. This study introduces a green synthesis of novel bimetallic nanoporous composite, CuO/Ag using lemon extract. The synthesized nanoporous material, CuO/Ag@lemon extract was characterized using several analytical techniques, including X-ray diffraction (XRD), transmission electron microscopy (TEM), scanning electron microscopy (SEM), and energy-dispersive X-ray spectroscopy (EDX). The CuO/Ag@lemon extract nanoparticles were immobilized on glassy carbon electrode (GCE) to prepare modified CuO/Ag@lemon extract-GCE interface. The electrocatalytic and electrochemical properties of the modified

electrode was investigated using cyclic voltammetry (CV), differential pulse voltammetry (DPV), and amperometry for detection of Vitamin D3. The DPV method displayed a linear response range of 0.02-22.5  $\mu\text{M}$  with a detection limit of 2.62 nM, while the amperometric method showed a broader linear range of 0.25-23.25  $\mu\text{M}$  with a detection limit of 2.70 nM with 82% modified electrode stability. The designed electrode exhibited a positive response to the addition of Vitamin D3 with electrooxidation, reaching steady-state within 3.4 seconds, with 87 % reproducibility within a day. The proposed method offers a rapid and sensitive platform for detection of Vitamin D3 with minimal interference from other molecules. The early diagnosis of Vitamin D3 deficiency using modified electrodes allows for early treatment, thereby preventing severe health complications.



## Development Of Low-Cost Bacterial Cellulose-Pomegranate Peel Extract-Based Antibacterial Composite for Potential Biomedical Applications

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This study was aimed to develop low-cost bacterial cellulose (BC)-based antibacterial composite with pomegranate (*Punica granatum* L.) peel extract (PGPE) for potential biomedical applications. BC was cost-effectively produced by utilizing food wastes, and PGPE was ex situ impregnated into its hydrogel. Field-emission scanning electron microscopic (FE-SEM) observation showed a nanofibrous and microporous morphology of pristine BC and confirmed the development of BC-PGPE composite. Fourier transform infrared (FTIR) spectroscopy indicated the chemical interaction of PGPE with BC nanofibers. BC-PGPE composite held 97 % water of its dry weight and retained it for more than 48 h. The BC-PGPE composite exhibited better reswelling capabilities than pristine BC after three consecutive re-wetting cycles. The antibacterial activity of the BC-PGPE composite was determined via minimum inhibitory concentration (MIC), minimum bactericidal concentration (MBQ), disc diffusion, and plate count methods. The PGPE extract showed good antimicrobial activity against *Staphylococcus aureus* (Gram-positive) and *Escherichia coli* (Gram-negative), both in the form of extract and composite with BC, with relatively better activity against the former. The BC-PGPE composite produced a 17 mm zone of inhibition against *S. aureus*, while no inhibition zone was formed against *E. coli*. Furthermore, BC-PGPE composite caused a 100 % and 50 % reduction in the growth of *S. aureus* and *E. coli*, respectively. The findings of this study indicate that BC-PGPE composite could be a promising antibacterial wound dressing material.



## Medicinal Property of Frankincense

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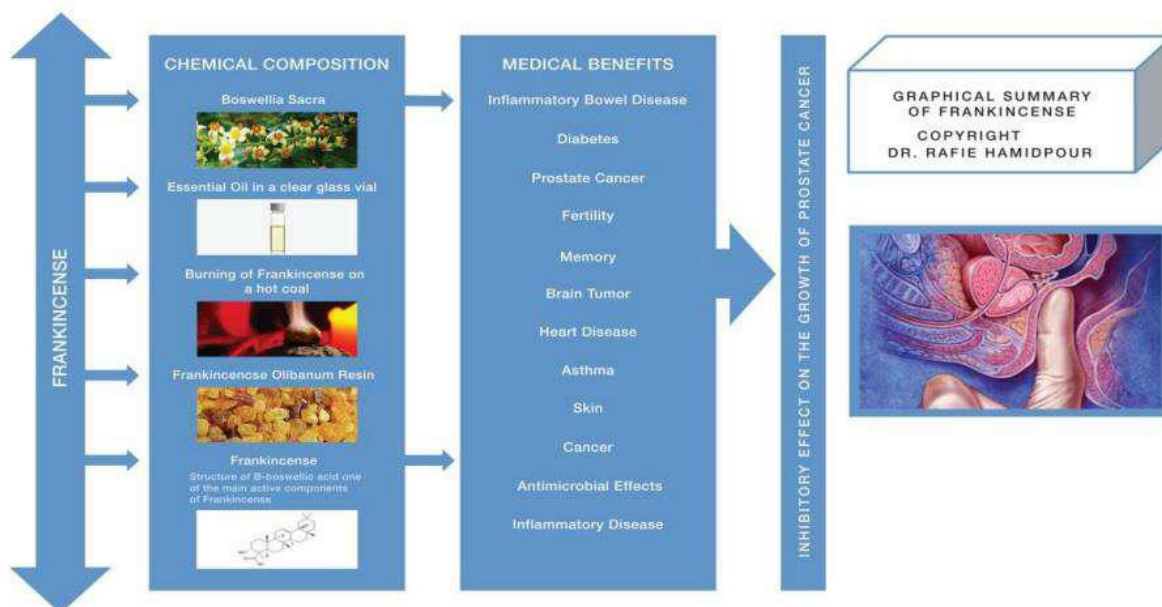
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Frankincense, the resinous extract from the trees of the genus *Boswellia*, has been used for centuries in ceremonial, cosmetic, cultural and as a traditional medicine to treat a variety of ailments especially inflammatory diseases including asthma, arthritis, cerebral edema, chronic pain syndrome, chronic bowel diseases, cancer and some other



illnesses. Boswellic acids are the active compounds of frankincense and AKBA (3-O-acetyl-11- keto- $\beta$ -boswellic acid) is the most important and effective acid among them. Some studies have shown that the use of frankincense can also improve the learning and enhance the memory in animals and human. The aim of our study is to determine that frankincense have a potential ability to be used as an alternative natural medicine not only for chronic and inflammatory diseases but also for the patients with brain and memory disorders.



### ***In silico* Molecular Modification, Prediction of Biological Activity and ADMET Studies Of Boswellic Acids in Search of Potent Anti-inflammatory Agents**

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Boswellic acids are the main bioactive constituents of Frankincense. However, their poor absorption poses a pharmacokinetic problem and limits their usefulness. Over the past two decades, computer aided drug design (CADD) techniques have been used to speed up the discovery of new drugs by identifying the lead compounds. The aim of the study was to carry out *in silico* molecular modification and prediction of biological activity and ADMET studies of Boswellic acids in search of potent anti-inflammatory agent(s). Bioisosteric groups were added to modify the chemical structures of six Boswellic acid derivatives in Chemskech and their bioactivities were predicted with the help of Molinspiration, ADMETsar and PASS software. A total of 8 to 12 structural modifications were made for each boswellic acid derivative. Out of 60 analogues; analogue number 2 of acetyl-beta-boswellic acid (ABA) was the best since the computational prediction results showed it to have the highest anti-inflammatory activity among all the analogues as well as better oral absorption and safety profile, however the other analogues are predicted to have lower anti-inflammatory action and more side effects than the parent compounds. Based on the structure activity relationship (SAR) studies, a lead compound predicted by the cheminformatic software as the most potent analogue having the best anti-inflammatory action and the least toxicity was identified. However further research is needed to synthesize and evaluate the potential of the lead compound.



## Antimicrobial Bacterial Cellulose–*Anogeissus Dhofarica*'s Extract Composites as Effective Wound Healing Agents

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Bacterial cellulose, produced by acetic acid bacteria, is widely explored for its biomedical application including wound healing, tissue engineering scaffold and blood vessels etc. owing to its nanofibrous morphology, excellent mechanical strength and high biocompatibility. However, the lack of antimicrobial properties limits its practical applications in biomedical fields. Composites of BC with antimicrobial materials including metal and metal oxide nanoparticles, antibiotics and plant extract are synthesized to impart antimicrobial property to native BC. In this study, we have prepared BC composite with extract from *Anogeissus dhofarica* (AD) plant indigenous to Dhofar region. This plant belongs the Combretaceae family and its extracts are used in herbal medicines typically for wound healing and treating some skin ailments like eczema and psoriasis. The BC-AD composites are prepared using ex-situ method, the plant bark and leaves were extracted using ethanol and followed BC incubation in the extract leading to BC-AD(B) and BC-AD(L), respectively. The composite films showed excellent water holding capacity and water release rate. The composite films were tested for their antimicrobial property against *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* (*S. aureus*) and the results indicated strong inhibition of the tested species. These results indicated that our composites are suitable for wound healing applications.



## Differential Expression of Oman's Wild Lavender, *Lavandula subnuda* for Chemical Composition Towards Medicinal and Aromatic Application

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Plants have been used directly or indirectly as medicines for over 5000 years as a source of antibiotics, antineoplastics, analgesics, and cardio-protective, among others. Approximately 70–90 % of the population in

developing countries continue to use ancient medicines based on plant extracts for treatment. Of late, the isolation and identification of biologically active compounds and molecules from nature have led to the discovery of new therapeutics, prompting the improvement of the health and pharmaceutical sectors. Phytochemicals revolve around the pharmaceutical industry's research and development (R&D) sector as a source of new molecules leading to the development of new novel drugs. Given the above, the present investigation addresses the differential nature of wild lavender (*Lavandula subnuda* Benth) plants of diverse locations in Oman with respect to their chemical composition of the essential oil in addition to morphological characters and chlorophyll contents of leaves to explore the possibility of isolating its prime chemical compounds on a commercial scale in perfumery industry. Composite samples of ten randomly selected plants were collected from wadi habitats of four diversified locations. Edaphic features of managed sites were recorded, and their soil chemical contents were determined following instructions using S1 Titan/Tracer 5/CTX equipment of Bruker developed based on energy dispersive X-ray fluorescence (EDXRF). Morphological traits were measured using a ruler, and chlorophyll contents were recorded using the at LEAF CHL Plus chlorophyll meter as at LEAF values. The essential oil was extracted using ETHO X's advanced microwave extraction system and analyzed for chemical compounds using GC-MS analysis on Shimadzu GC-2010 Plus gas chromatograph. The experimental data were analyzed statistically, wherever required, by applying basic statistics of the EXCEL -16 version. The results indicated that in general, the *Lavandula subnuda* plants of locations of high altitudes had higher expressivity in all the morphological traits 5 and chlorophyll contents than those of low altitudes. The essential oil recovery, however, was found to be higher from the plant samples of lower altitudes (0.70 to 0.79 % (w/w)) than from those of higher mountains/ altitudes (0.15 to 0.18 % (w/w)). The pattern of values of commonly occurring chemical contents of essential oils was different. Each essential oil's top ten chemical compounds contributed about 80 % of the total in four locations. Of the ten top chemical compounds, eight compounds, namely D-Germacrene (42.67 %) from Wadi Al-Khod, Estragole (32 %) and Linalool (23.89 %) from Wadi Halban, trans-Borneol (23.46 %) and 4-Terpineol (18.7 3 %) from Wadi Najd Al-Waqba and Kessane (18.6 0 %), beta-cis-Caryophyllene (13.68 %) and beta Elemene (10.618 %) from Wadi Al-Hayul, were found highest in quantity and had huge potential for further application. It is concluded that there exists a higher possibility of adapting Good Agriculture Practice (GAP) to produce the highest yield of herbage yield of vegetative parts of *Lavandula subnuda* plants vegetative parts based on morphological features under wild conditions to extract these compounds on a commercial scale in both the pharmaceutical and perfumery industries.



## Phytochemical Screening and Chemical Analysis of One Omani Medicinal Plant

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Al-Mandiya plant is one of medicine plants found in Oman, Arabian Gulf and some African countries generally called (*Anticharis* Endl). It is available in two types in the Sultanate of Oman: *Anticharis arabica* Endl and *Anticharis glandulosa* Asch. It is considered a seasonal plant (Ephemeral) and has certain places where it can be found (Endemic). For long time, Omani people are using this plant to wash utensils and clothes because of its foamy properties. It has several local names, including Al-Mandiya, Al-Huraydah and Shajarat Al-Mutawa, according to the regions in the Sultanate of Oman. In this work, the isolation of saponin using various solvents from two species of *Anticharis* Endl were done. *Anticharis sp* is a viscose plant belonging to the family Scrophulariaceae. The saponin was isolated from all parts of plant (leaves and twigs), which is isolated, and extract are obtained. Positive results are achieved using a qualitative test in foam test and emulsion test. A quantitative test was also done to find the total saponins content and it's found to be 16.12 % in the *Anticharis* Endl plant. In addition, FTIR analysis has been done for both fresh and dry sample plant. The FTIR analysis of saponin structure shows stretching vibrations the peaks at 3380 cm<sup>-1</sup> for primary amine N-H stretch, 2870 cm<sup>-1</sup> (methyl-CH<sub>3</sub>), 1600 cm<sup>-1</sup> (C=C conjugated), 1270 cm<sup>-1</sup> (aromatic ethers, aryl -O stretch), 1054.4 cm<sup>-1</sup> (alkylsubstituted ether, C-O stretch) which indicated the presence of these functional groups. The primary results of biological activities indicate a promising result in which ethanol extract is more active for two types of bacteria (*Staphylococcus*,

*Micrococcus*), while water extract high activated for *Escherichia coli* species. For antifungal activity, we get the better results for ethanol extract as well against *Rhizopus*.