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НИЗЬКИЙ РІВЕНЬ ПОШИРЕНОСТІ COVID-19 У ЛАОСІ ТА КАМБОДЖІ: ЧИ ДІЄТА ВІДІГРАЄ РОЛЬ?

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LOW PREVALENCE OF COVID-19 IN LAOS AND CAMBODIA: DOES DIET PLAY A ROLE?

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Реферат

Мета *дослідження полягала у огляді наукових джерел для з'ясування можливої залежності між харчовими звичками населення Лаосу, Камбоджі та В'єтнаму й зменшеним впливом COVID19.*

Матеріали і методи. *Використано методи збору, систематизації, аналізу та узагальнення інформаційних даних. Проведено аналіз літератури в наукових базах даних й аналітичних платформах за ключовими словами; у знайдених джерелах також проаналізовано усі релевантні посилання.*

Результати й обговорення. *Спалах коронавірусної хвороби (COVID-19) - це триваюча пандемія, спричинена високопатогенним коронавірусом людини, відомим як SARS-CoV2. Згідно актуальних епідеміологічних даних, понад 500 мільйонів випадків COVID-19 зафіксовано у понад 180 країнах світу. При інфікуванні верхніх дихальних шляхів низькопатогенними людськими коронавірусами (HCoV) зазвичай розвивається легка форма респіраторного захворювання. Проте при ураженні нижніх дихальних шляхів високопатогенними HCoV, такими як SARS-CoV2, може виникати гострий респіраторний дистрес-синдром (ГРДС) і навіть пневмонія з летальним результатом. Дана ситуація викликає необхідність термінового пошуку ефективних заходів лікування. Дуже низькі рівні захворюваності на SARS-CoV-2 у Лаосі та Камбоджі та смертності від COVID-19 у В'єтнамі та Лаосі викликають надзвичайну зацікавленість, особливо з урахуванням раннього контакту населення із вірусом, постійних зв'язків з Китаєм, відносної бідності та високої щільності населення. Про використання деяких спецій і ароматичних трав як природних засобів для лікування багатьох хвороб, у тому числі вірусних інфекцій, відомо з давніх-давен. У дослідженні розглянуто три невід'ємні елементи лаоської, камбоджійської та в'єтнамської дієт - особливі кулінарні спеції та трави, кокосова олія і пальмова олія, багата насиченими жирними кислотами, а також фермен-*

Abstract

The study **aims** *to review the involvement of different dietary habits in Laotian, Cambodian, and Vietnamese populations in reducing COVID19 impact.*

Materials and Methods. *The methods of collection, systematization, analysis and generalization of information data have been used. The analysis of literature in scientific databases and analytical platforms by the listed keywords has been performed; all relevant references in the found sources have also been reviewed.*

Results and Discussion. *Coronavirus disease (COVID-19) outbreak is an ongoing pandemic caused by a highly pathogenic human coronavirus known as SARS-CoV2. Current epidemiology reported that more than 500 million cases of COVID-19 occurred in more than 180 countries worldwide. When the upper respiratory tract gets infected by low pathogenetic HCoVs, it typically triggers a mild respiratory disease. In contrast, when the lower airways get infected by highly pathogenic HCoVs, such as SARS-CoV2, acute respiratory distress syndrome (ARDS) may occur and even fatal pneumonia. Such a situation causes the need for an urgent search of effective treatment measures. A very low incidence of SARS-CoV-2 in Laos and Cambodia, as well as low mortality rate due to COVID-19 in Vietnam and Laos, are extremely interesting, especially because of their early exposure to the virus, continuing ties to China, relative poverty, and high population density. The use of several spices and aromatic herbs as natural treatments for several illnesses, including viral infections, has been reported since a long time ago. The research reviewed three integral elements of Laotian, Cambodian, and Vietnamese diets, such as special culinary spices and herbs, coconut oil, and palm oil-rich for saturated fatty acids as well as fermented shrimp paste. Environmental and population genetic causes may be forwarded but moreover local dietary habits may have even a role in this evidence. Therefore, all these items highlight the possibility of a significant contribution of local cuisine and diet into the impact on*

тована паста з креветок. Екологічні та популяційно-генетичні ознаки здатні передаватись, але місцеві харчові звички можуть відігравати додаткову роль. Таким чином, наведені дані демонструють можливість значного внеску місцевої кухні та дієти у вплив на відповідні протизапальні та імунорезистентні механізми людської популяції.

Висновки. *Огляд дієти мешканців В'єтнаму, Камбоджі та Лаосу допоміг припустити, які харчові чинники можуть сприяти зменшенню важкості симптомів SARS-CoV-2.*

appropriate anti-inflammatory and immune-resistant mechanisms of the human population.

Conclusions. *The review on Vietnam, Cambodia, and Laos inhabitants' diet helped to suggest the dietary factors having the contributing potential of reducing the severity of SARS-CoV-2 symptoms.*

Introduction

As of April 2022, coronavirus disease 2019 (COVID-19) has been confirmed in over 500 million people worldwide, with a mortality rate of approximately 1·24% [1]. The analysis of WHO statistics [1] revealed some interesting data related to SARS-CoV-2 in some of Indo-Chinese countries, namely: very low incidence rate in Laos (2,73%) and Cambodia (0,81%) in comparison with its global rate (6,41%), as well as low mortality rate in Vietnam (0,42%) and Laos (0,36%).

Human coronaviruses (HCoVs) are broadly divided into low and highly pathogenic. When the upper respiratory tract becomes infected by low pathogenetic HCoVs, a mild, cold-like respiratory ailment typically occurs. In contrast, when the lower respiratory airways get affected by highly pathogenic ones, middle east respiratory syndrome CoV (MERS-CoV), severe acute respiratory syndrome CoV (SARS-CoV), and fatal pneumonia may occur [2]. Severe pneumonia due to HCoVs is commonly associated with rapid virus replication, inflammatory cells infiltration, and raised proinflammatory cytokines/chemokines reaction that lead to acute respiratory distress syndrome (ARDS) and acute lung injury (ALI) [2]. This is particularly true for SARS-CoV2, the 2019 SRAS coronavirus. Recent experimental investigations have strongly implied that the immunopathological consequences caused by the coronavirus play a pivotal impact in fatal pneumonia caused by HCoV infections [2].

Viral respiratory infection (VRI) symptoms are usually significant due to immune responses to the infecting agent. More importantly, severe influenza is partly due to what has been dubbed "cytokine storm", a hyper-reaction of the immune system to certain influenza strains [3]. Such a situation triggered the need for an urgent search for effective treatment measures.

It is tempting to speculate that inflammation-modulating medicinal plants are keys both to decrease symptoms and to prevent severe outcomes, at least in cases of influenza infection. In addition, these herbs generally have immunostimulant effects if the risk of exacerbation the VRI symptoms or developing cytokine storms worsens. However, with concomitant inflammation-modulating impact, this potential issue is avoided [4]. On the other side, herbs also have a significant potential in preventing VRI, with several botanical extracts demonstrating such ability in clinical trials [4]. Indeed, numerous safe and effective herbal treatments have been applied for preventive purposes against VRI. So, herbs provide a much-needed alternative to ineffective antibiotics, while still aiding VRI patients to feel they are receiving useful remedies, thereby decreasing the tendency to antibiotics demand [4].

In China, most SARS-CoV-2 patients (>85 %) receive treatment according to the Traditional Chinese Medicine (TCM) approach [5]. Because of the SARS-CoV-2 and SARS-CoV homology, concerning the pathogenesis, epidemiology, and genomics, as well as the frequent application of TCM modalities in the SARS-CoV treatment, clinical data have shown that TCM has beneficial therapeutic effects in patients with SARS [5, 6]. Thus, herbal formulations can contribute significantly as a complementary treatment for patients with severe

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VRI, as well as nutrition is also of great importance for health promotion and maintenance [7].

Objective

In this paper we aimed to review how the different dietary habits in Laotian, Cambodian, and Vietnamese populations should be involved to reduce COVID19 impact.

Materials and Methods

The generally accepted research methods have been applied, namely: collection, systematization, analysis and generalization of information data. The analysis of literature sources in scientific databases and analytical platforms (Pubmed, ScienceDirect, Springer Link, Wiley, Researchgate, Google Scholar) by the listed keywords has been carried out; all relevant references in the received publications have also been reviewed.

Spices and Specific Edible Plants of Indochina

Culinary herbs and spices have been used for decades in beverages and foods as a way to increase flavor, color, and aroma. Phytochemicals present in these spices and herbs have significant immunomodulatory, antiviral, antibacterial, anti-inflammatory and antioxidant effects (Figure 1) [8, 9, 18, 10-17]. The interest in identifying active principles from medicinal plants and spices is growing exponentially, as they prevent against diet-related disorders by modulating immunity, inflammation, and oxidative stress [19]. Phytochemicals that have been demonstrated to possess antiviral activity can also be applied as promising prophylactic bioactive substances, candidates for SARS-CoV-2. Several reports, investigating active principles from dietary sources having the potential to impede virus proliferation, are currently available [20, 21]. A recent study reported that these dietary agents with an application in vitro and molecular docking were predicted to be COVID-19' drug candidate as the best potential inhibitors against Main Protease (Mpro) and other viruses' strain [21]. In the following subsections, the most abundant plant-food-derived phytochemicals, consumed in Laotian, Cambodian, and Vietnamese diets, are briefly discussed.

Green tea

Epigallocatechin gallate (EGCG) is a polyphenolic substance found in green tea, which, due to its antioxidant action, affects influenza-infected cells [22]. Widespread in medicinal plants triterpenoids, flavonoids, and polyphenols may be potentially protective in severe influenza in the case of cytokine storm [3].

Chili pepper

Capsaicin, dihydrocapsaicin, capsiate, dihydrocapsiate, present in chili pepper, have demonstrated antioxidant and anti-inflammatory properties. Capsaicin possesses antioxidant activity by mitigating oxidative stress in various tissues or organs, both in vitro and in animal models, being able to inhibit neutrophil (inflammatory cells) migration towards the inflammatory focus, reduce vascular permeability and proinflammatory cytokines production in animals [19].

Rosemary, Cinnamon, and Clove

In vitro findings have revealed that rosemary can suppress the activation of inflammatory cytokines, including the nuclear factor kappaB (NF-kB) and interleukin (IL)-1 , and shut down the cyclooxygenase (COX)-2 activity, involved in inflammation [19].

Cinnamon-derived cinnamaldehyde is able to reduce inflammation in an arthritis model in vivo via inhibiting cytokines, such as IL-2, IL-4, and interferon (IFN)-γ [19]. When mice were treated over 4 weeks with *Cinnamomum osmophloeum* leaf essential oil, no significant cytokine-modulatory effects were observed. However, the serum levels of IL-10, IL-4, and IL-2, but not IFN-γ, increased significantly in the animals that were treated with cinnamaldehyde (1 mg/kg b.w.) for 4 weeks [23].

Due to its prominent medicinal attributes, the essential oil and extract of clove (*Syzygium aromaticum*) have been frequently used. Eugenol, the main active principle present in

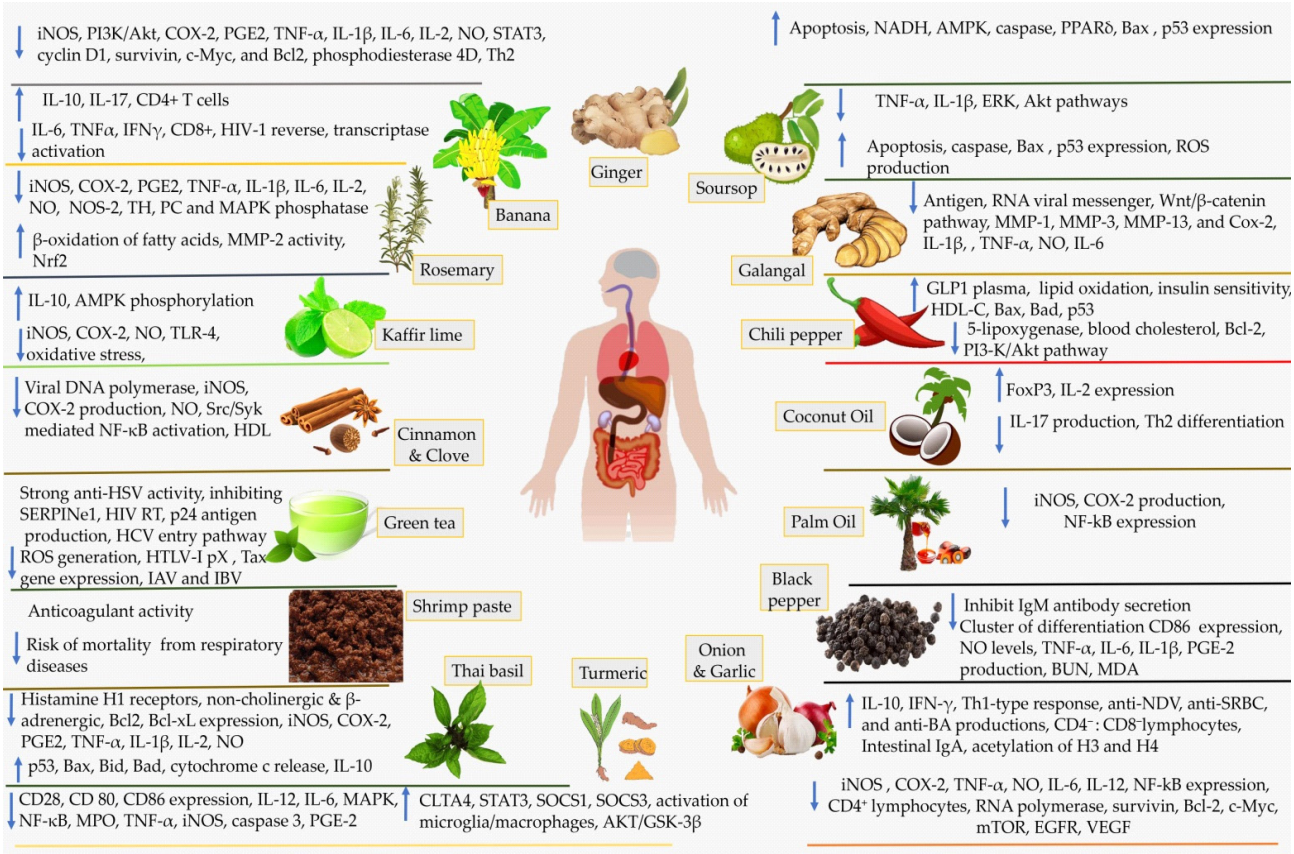

Figure 1

Commonly used dietary agents in Laos, Cambodia, and Vietnam and their possible roles in preventing SARS CoV-2 AKT: Protein kinase B; AMPK: Adenosine monophosphate-activated protein kinase; BA: Bacterial; BAX: Bcl-2-associated X protein; BCL2: B-cell lymphoma 2; Bcl-xL: B-cell lymphoma-extra-large; BID and BAD: BH3-only proteins; BUN: Blood urea nitrogen; Caspases: Cysteine-aspartic proteases; CD4: cluster of differentiation 4; CLTA4: Cytotoxic T-lymphocyte-associated protein 4; c-Myc: Avian myelocytomatosis virus oncogene cellular homolog; COX: Cyclooxygenase; EGFR: Epidermal growth factor receptor; ERK: Extracellular-signal-regulated kinase; FOXP3: Forkhead box protein P3; GLP-1: Glucagon-like peptide 1; GLP-1: Glucagon-like peptide-1; GSK3: Glycogen Synthase Kinase-3; HCV: Hepatitis C virus; HDL: High-density lipoprotein; HIV-RT: Human immunodeficiency virus type 1 reverse transcriptase; HTLV-1: Human T-cell lymphotropic virus type 1; IAV and IBV: Type A and B influenza viruses; IFN: Interferons; Ig: Immunoglobulin; IgM: Immunoglobulin M; IL: Interleukin; iNOS: inducible Nitric Oxide Synthase; MAPK: Mitogen-Activated Protein Kinase; MDA: Malondialdehyde; MMPs: Matrix metalloproteinases; MPO: Myeloperoxidase; mTOR: Mammalian target of rapamycin; NADPH: Nicotinamide adenine dinucleotide phosphate; NDV: Newcastle disease virus; NF-κB: Nuclear Factor kappa B; NO: Nitric Oxide; Nrf2: Nuclear factor erythroid 2-related factor 2; P24 antigen: HIV-1 capsid protein; PGE2: Prostaglandin E_2; PI3K: Phosphatidylinositol-3-kinase; PI3K: Phosphoinositide 3-kinase; PKA: Protein kinase A; PPARγ: Peroxisome proliferator-activated receptor gamma; ROS: Reactive oxygen species; ROS: Reactive oxygen species; SERPINE-1: Endothelial plasminogen activator inhibitor-1; SOCS: Suppressor of cytokine signaling; SRBC: Sheep red blood cells; SRC: Proto-oncogene tyrosine-protein kinase; STAT: Signal transducers and activators of transcription; SYK: Nonreceptor tyrosine kinase; TAX: Transactivator from the X-gene; TH2: T helper 2; TLR: Toll-like receptor; TNF: Tumor necrosis factor; TPA: 12-O-tetradecanoyl-phorbol-13-acetate; TREM: Triggering receptor expressed on myeloid cells; VCAM: Vascular cell adhesion molecule; VEGF: Vascular endothelial growth factor; WNT: Wingless and int-1

clove, has been reported to have several biological attributes. Indeed, it has been shown that clove (100 µg/well) inhibits IL-6, IL-10, and IL-1β production. Also, it affects all cytokines levels, concerning the lipopolysaccharide (LPS) challenge, without affecting the IL-1β and IL-10, and impeding the IL-6 production. Eugenol has an impact (50 or 100 µg/well) on IL-6 production, preventing that LPS efficiently affects its addition. On the other side, the IL-10 production is significantly counteracted by the impact of LPS, when it is added after LPS

incubation. Clove exhibits anti-inflammatory/ immunomodulatory properties through inhibiting the LPS action. The possible mechanisms of activity of eugenol, which is a primary active substance in clove extract, seem to involve the NF-κB pathway suppression [24].

Galangal and Ginger

Galangal (*Alpinia officinalis*) and ginger (*Zingiber officinale*) are close relatives and spices with remarkable anti-inflammatory properties. It has been documented that ginger decreases the concentrations of both tumor necrosis factor-alpha (TNF-α) and IL-1β, cytokines linked to the destructive immune reaction to COVID-19 [25], at the same time that enhance the endogenous antioxidant effects. The juice from ginger roots is a popular component of Vietnamese and some other South Asian cuisines for flavoring dishes, including seafood, meat, and vegetarian dishes [26].

The prostaglandin synthesis can be terminated by ginger through inhibition of COX-2 and COX-1. Moreover, ginger suppresses the biosynthesis of leukotrienes through 5-lipoxygenase inhibition. Ginger also exerts other characteristic pharmacological properties. For instance, it has been demonstrated that a ginger extract (EV.EXT.77) obtained from *Alpinia galanga* and *Zingiber officinale*, was able to impede gene induction associated with inflammatory responses, which include genes encoding chemokines, cytokines and COX-2 [27]. Ginger extracts also retard beta-amyloid peptide-induced cytokine and chemokine expression in cultured THP-1 monocytes [28]. On the other side, it has been shown that a hexane fraction of *Zingiberis Rhizoma crudus* extract can suppress the production of proinflammatory cytokines and nitric oxide in BV2 microglial cells stimulated by LPS via NF-κB pathway [29]. The aqueous and ethanol extracts from ginger in STZ-induced diabetic rats also raised the intracellular action of superoxide dismutase (SOD), catalase (CAT), and glutathione (GSH). However, the extracts led to a substantial decline in the levels of malondialdehyde (MDA) and TNF-α. Thus, the mechanism of antidiabetic effects of ginger may be partly due to inhibition of oxidative stress and inflammatory activity [30]. The effect of ginger supplementation on proinflammatory cytokines levels in older osteoarthritic patients was also confirmed in a randomized controlled clinical trial. Ginger supplementation revealed promising benefits for knee osteoarthritis since, at three months, both cytokines (TNF-α and IL-1β) decreased in the ginger group when compared to the placebo group [31]. In another study, it was also shown that ginger might reduce joint swelling, cartilage damage as well as serum inflammatory cytokines levels, associated with arthritis and joint muscle pain. In addition, it was able to accelerate muscle strength recovery after intense exercise [19]. Thus, ginger gingerols, shogaols, paradols, and zingerone have remarkable antioxidant and anti-inflammatory effects. Ginger and its extracts exhibited substantial free radical scavenging activities, inhibited inflammatory mediators (e.g., nitric oxide and prostaglandin E2) production, suppressed proinflammatory transcription factor (NF-κB) and the activity of inflammatory cytokines (e.g., TNF-α) as well as of COX-2 *in vitro* [19]. Finally, galangal rhizomes through the form of powder are used in Vietnamese, Laotian, Cambodian and other Asian cuisines in spice pastes, stews and soups. For example, a mixture of galangal and lime juice is used as a tonic in some parts of Southeast Asia [32].

Turmeric

In the southeast and south Asian forests, turmeric is growing wild. It is used in various Asian dishes as a key ingredient [32], mostly in savory, but also in some sweet dishes. In Vietnam, turmeric is used through the form of powder for colorant and flavor enhancer purposes in individual dishes, such as Banh Xeo, Banh Khot and Mi Quang [32], but also in various other Vietnamese soups and stir-fried dishes. The rhizomes of fresh turmeric are used in many Thai dishes, especially in the cuisine in the south of Thailand, such as yellow curry paste [32].

Regarding turmeric bioactive effects,

curcumin is an important active component, widely recognized for its pronounced antioxidant, anti-inflammatory, and anti-atherosclerotic properties. Research has shown that curcumin affects the monocyte chemoattractant protein-1 (MCP-1) production, which is induced by oxidized low-density lipoprotein (ox-LDL) and cholesterol efflux [3,33]. This suggests that curcumin is a vasoprotective agent related to its anti-inflammatory and anti-atherosclerotic effects [33]. In a randomized controlled study, eight weeks of curcumin supplementation (1g/day) was shown to significantly lower the serum levels of proinflammatory cytokines in individuals with metabolic syndrome. The between-group comparison revealed a more pronounced lowering potential in serum levels of IL-6, TNF- α, MCP-1, and transforming growth factor (TGF)-β in the curcumin-treated group when compared to the placebo group [34].

Onion and Garlic

In Vietnam, fermented Welsh onions, often called dua hanh, is traditionally served for the Vietnamese New Year (Tet). A special sauce mahanh is made from Welsh onions, which are fried in oil. It is used in different Vietnamese dishes. In a rice porridge, called chao hanh, the main ingredient is Welsh, which is applied for the treatment of common cold [32]. The different species or cultivars of "spring onion" include *Allium cepa*, *Allium chinense*, *Allium proliferum*, and *Allium fistulosum*. Bulbs are not formed by the Welsh onion. In the West, it is grown nearly exclusively as salad onion or spring onion. However, in Asia, Welsh onion is of great importance, being used both fresh and cooked [32]. Congchi decoction is commonly prescribed in China for treating "light exterior wind-cold syndrome", and has been recorded in many medical books. Fistular onion stalk has diaphoretic effects and accelerates Yang Qi. Also, it is used to treat restlessness after cholera, febrile disease, thoracic obstruction, Yin-Yang toxin syndrome, and bellyache due to spleen Qi deficiency [35].

In Asia, Vietnam, Chili Garlic Sauce is a highly popular condiment [26]. In the UK, a randomized, double-blind study with 146 adults assessed the effects of garlic supplementation (180 mg allicin/day) or placebo over 12 weeks in the peak of cold and influenza season. As the main findings, it was stated that the number of colds in individuals who took garlic was approximately 1/3 of these who got the placebo. Also, both the severity and duration of VRI symptoms were significantly reduced in the garlic-treated group when compared to placebo [4, 36, 37].

Kaffir lime and other citrus fruits

Kaffir lime (*Citrus hystrix*, Mauritius papeda, or makrut lime) is a citrus fruit originally found in southern China and tropical Southeast Asia. Kaffir limes differ from regular limes in that they are very bitter with bumpy skin. Kaffir leaves and fruit are consumed in Southeast Asia cuisine, and its essential oil is used in perfumery. The citrus fragrance emitted from its crushed and rind leaves is intense. In Lao, Tai and Cambodian cuisines, the leaves are typically used in different dishes. The Cambodian sauce Tuk Meric, which only consists of fresh lime juice, blended with ground black pepper, is one of the simplest to make. The Cambodian fish sauce Tuk Trey contains garlic, red chilies seeded, peanuts, and lime juice [32]. In Vietnamese cuisine, the leaves are used to give chicken dishes fragrance as well as to lower the odor of steaming snails. The whole fruits are candied in Cambodia for eating [32].

The essential oil obtained from the *C. hystrix* fruits peel is a colorless or light-yellow liquid with a strong citrus scent. The major compounds present in oil include β-pinene, limonene, terpinen-4-ol, α-pinene, α-terpinene, γ-terpinene, and α-terpineol. Prominent antibacterial effects have been stated to the *C. hystrix* essential oil, assessed by disc diffusion and serial macro dilution methods against 50 multidrug-resistant *Acinetobacter baumannii* strains. The results revealed a good activity against the tested strains, expressed by minimal inhibitory concentrations (MICs) ranging from 0.125 to 1 μl/mL [38]. Srisukh et al. [39] investigated the effect of the individual compounds present in *C. hystrix* leaves and fruit

peel essential oil against the pathogens triggering respiratory tract infections. The authors stated that α-terpineol and terpinen-4-ol were more active than the entire mixture of compounds, while limonene, the most abundant component present in the essential oil, when used separately, revealed significantly less activity against *A. baumannii* [39, 40]. The effect was also measured towards the clinical strains of *A. baumannii*, *Streptococcus pneumoniae*, *Haemophilus influenzae*, *Moraxella catarrhalis* and *Staphylococcus aureus*. Although the results confirmed the activity of both oils, particularly against *M. catarrhalis*, the lime peel oil proved to be much more potent, being effective at significantly lower doses. The efficacy of *C. hystrix* essential oil from leaves and peel on *A. baumannii* revealed MIC values as follows: 2.10-17 mg/mL and 1.10-4.40 mg/mL, respectively [38]. On the other side, *Citrus sinensis* (sweet orange) peel extract notably prevented liver injury through lowering the levels of both TNF-α and INF-γ as well as of regulatory T (reg-T) cells, while increased the IL-10 levels [41].

Thai basil

Ocimum basilicum (OB), often known a Thai basil or sweet basil, is a common ingredient in the Southeast Asian cuisines, which include the cuisines of Thailand, Vietnam, Cambodia, and Laos. Three types of basil are widely applied in Thai cuisine. First, Thai basil, also called horapha, which is commonly used in Southeast Asia, is prominent in Vietnamese cuisine. Also, it is often used when Asian food is made in Western kitchens. Second, holy basil (*Ocimum tenuiflorum*), or kaphrao; and, finally, lemon basil (*Ocimum citriodorum*) [32].

Thai basil is common in traditional Chinese and Indian medicine. It is a well-known medicinal herb, which are used in preparations for the treatment of various disorders, including upper respiratory tract infections as well as on wound healing. Purified components and extracts of Thai basil have been investigated in the identification of potential antiviral effects against different types of viruses. For example, it has been shown that the Thai basil extracts (ethanol and crude aqueous) and the purified components (ursolic acid, apigenin and linalool) exhibit a broad-spectrum antiviral activity. Interestingly, it has been shown that ursolic acid affects the replication phases of Coxsackievirus B (CVB1) and enterovirus 71 (EV71) [42].

On the other hand, bovine viral diarrhea virus (BVDV) has been used as a model for future antiviral hepatitis C virus (HCV) studies. It was stated that Thai basil exerted antiviral activity against BVDV. In one study, it was shown that 1,8-cineole [cytotoxic concentration $(CC)_{50}$=2996.10μg/mL] and camphor (CC_{50}=4420.12μg/mL) reveal the lowest cytotoxicity. In a viricidal assay, the antiviral activities (SI) of camphor and 1,8-cineol were13.88 and 9.05, respectively, with monoterpenes revealing the highest potential. This suggests that these compounds directly affect viral particles [43].

Moreover, in a study, it was stated that OB crude methanol extract exerts good inhibitory effects on the proliferative response to peripheral blood mononuclear cells (PBMC) in mitogenic lymphocyte proliferation assays 44. Furthermore, studies of gene expression on LPS-induced proinflammatory cytokines production, like TNF-α, IL-1β, and IL-2, revealed that the extract was able to downregulate these markers. It was also capable of suppressing inducible nitric oxide synthase (iNOS) and, subsequently, nitric oxide (NO) production in RAW 264.7 macrophages time-dependently stimulated by LPS. OB crude methanol extract also inhibited the key proinflammatory mediators and cytokines, displaying anti-inflammatory effects [44]. In addition, the immunomodulatory and anti-inflammatory effects of a hydroethanolic extract from OB leaves were studied in ovalbumin sensitized animals. The significant elevation of IgE, IL-4, PLA_2, as well as of the TP concentrations was decreased following OB extract application, with all pathological lung indices being also ameliorated and the IFN-γ/IL-4 ratio revealing a reduction, with these effects being more pronounced when compared to those observed in animals treated with dexamethasone [45].

Soursop

The soursop fruit from *Annona muricata*, which is a broadleaf, evergreen flowering tree, is called tearb barung in Cambodia, which means "western custard-apple fruit." In some parts of the Caribbean, Latin America, Southeast Asia, Pacific, and Africa, the fruit is particularly popular and widespread cultivated. Due to this, soursop-derived products are available in many countries, where they are consumed, also in branded beverage and food products [32].

The aqueous extract from A. muricata leaves (AM) has been tested against dengue virus type 2 (DENV-2), using a cell viability assay to determine its cytotoxic potential. In Vero cells, the CC_{50} of AM was found to be ~2.5 mg/mL, and the 50% effective concentration (EC50) was approximately 0.20 mg/mL. Against DENV-2, the AM selectivity index was >10. This indicates that AM has antiviral potential. When AM-treated cells were investigated, post-treatment revealed a more efficient inhibition of viral replication in comparison to pre-treatment. These findings indicated that AM has a good potential to be used in the development of nature-based antiviral drugs [46]. Moreover, AM ethanol extract was screened for its activity against *Herpes simplex* virus-1 (HSV-1) and a clinical isolate, obtained from the human keratitis abrasion. The ability of the extract to inhibit the HSV-1 cytopathic effect on Vero cells, which is indicative of the anti-HSV-1 potential (MIC=1 mg/mL), has been observed [47].

Black pepper

Peppercorns and the ground pepper, obtained from them, might just be named black pepper (unripe fruit that is cooked and dried), white pepper (seeds of ripe fruit), and green pepper (unripe fruit that is dried) [32]. Pepper (*Piper nigrum*) has its origin in Asia (Southeast and South). Since at least 2 BCE, its consumption is known in Indian cooking. Ground white pepper is often used in Thai and Chinese cuisine, applied in dishes, including salad, mashed potatoes and light-colored sauces. Fresh, unpreserved green pepper drupes, characterized by its fresh and spicy flavor and bright aroma, are particularly used in Thai cuisine; if not preserved or dried, they decay fast. Vietnam is one of the world's largest producers and exporters of pepper. In 2008, the country produced 34% of the world's pepper crops [32].

Research has shown that piperine, the most abundant active principle found in black pepper, can reduce several proinflammatory cytokines. Piperine can reduce the gene expression of IL-1β, IL-6, TNF-α, IL-12p40, and GM-CSF. Also, it was found that piperine at 2.5, 5, and 10 μg/mL dose-dependently inhibited the collagen matrix invasion in B16F-10 melanoma cells, besides being able to inhibit matrix metalloproteinase production. The nuclear translocation of p50, p65, c-Rel subunits of NF-κB, as well as of other transcription factors, including ATF-2, CREB, and c-Fos, is also inhibited by piperine treatment [48].

Banana

Banana lectin (BanLec), a dimeric protein found in fruit pulp, has revealed an interesting ability to modulate the immune cell functioning *in vitro*. To assess the *in vivo* immune response, purified banana lectin was given orally to mice for seven days. The cytokines levels measured in peripheral blood of mice demonstrated an increase in IL-10, TNF-α, and IL-17, and a decrease in IL-6 and IFN-γ levels. In mice thymus, it was also stated a reduction in the number of CD8+ and an elevation in the number of CD4+ T cells after oral administration of banana lectin. These *in vivo* findings demonstrated that natural banana lectin has extraordinary immunomodulatory properties [49]. A homodimeric, fructose-binding lectin from Del Monte bananas elucidated in murine splenocytes a mitogenic response, being evident an induction of the INF-γ, IL-2, and TNF-α in splenocytes. Banana lectin was also capable of inhibiting leukemia (L1210) and hepatoma (HepG2) cell proliferation as well as activate HIV-1 reverse transcriptase [50].

Coconut Oil and Palm Oil

The "tropical oils," i.e., coconut and palm oils,

contain lauric and myristic acids, both of which can help in protecting cartilage [51]. Briefly, coconut milk is a commonly consumed food ingredient in Southeast Asia, but also in many tropical cuisines, such as Burmese, Cambodian, Filipino, Indian, Indonesian, Malaysian, Singaporean, Sri Lankan, Thai, Vietnamese, Chinese Malaysian, and Southern Chinese. Coconut milk is also the basis of many Indonesian, Malaysian, Sri Lankan, and Thai curries [32]. The coconut oil, extracted from the coconut kernel, is unique edible oil. Lauric acid, the most abundant fatty acid in coconut oil, accounting for 45-53% of its fatty acid content, is relatively uncommon outside of coconuts. In the tropics, where coconut oil is commonly used in the cuisine, lauric acid is an important dietary component [52]. Research has shown that the antimicrobial activity of monolaurin and lauric acid is significant against various fungi, gram-positive bacteria, and even viruses [52]. Indeed, n-3 polyunsaturated fatty acids (PUFA) are potent anti-inflammatory agents and have been shown useful in treating several osteoarticular disorders, including rheumatoid arthritis (RA). Recent studies have suggested that n-3 PUFAs could attenuate arthritis through increasing the expression of FoxP3 and the differentiation of regulatory T cells while reducing IL-17 production. Therefore, dietary supplementation of n-3 PUFAs could have therapeutic potential for the treatment of RA [53]. Various mediators of osteoarthritis process are associated with important proinflammatory cytokines, such as TNFα, IL-1β, IL-6, IL-17, IL-18, and IL-15, and anti-inflammatory cytokines, including IL-13, IL-4, and IL-10 production [54].

In obesity, chronic inflammation and biomechanical stress are also linked with osteoarthritis. In the plasma of dietary-induced obese mice, at least two increased metabolites (lactate and stearic acid) have been determined. Stearic acid has been found to potentiate lactic acid dehydrogenase (LDH)-a-dependent lactate production, which further stabilizes the hypoxia-inducible factor 1-alpha (HIF1α) protein, and increases vascular endothelial growth factor (VEGF) as well as proinflammatory cytokine expression in mouse primary chondrocytes. Treatment with HIF1α and LDH-a inhibitors notably attenuated high-fat diet- or stearic acid-stimulated proinflammatory cytokines production *in vitro* and *in vivo*. A positive association between cartilage HIF1α, plasma lactate, and cytokine levels with body mass index (BMI) has been revealed in osteoarthritic individuals [55]. The proinflammatory cytokines secretion was also induced by stearate, but not by the shorter chain fatty acids, myristate, and laurate, or linoleate [56].

Indeed, increasing evidence has shown that saturated and unsaturated fatty acids (FAs) impact the effector and regulatory functions of innate and adaptive immune cells by changing cell membrane composition and fluidity and by acting in specific receptors. Thus, an impaired balance of saturated/unsaturated FAs, as well as *n-6/n*-3 PUFAs, might lead to the development of various allergic, autoimmune, and metabolic ailments. Lauric acid exhibits proinflammatory effects *in vitro*; for instance, it increases in T cell cultures IL-2 expression and develops an additive effect on IL-17 and granulocyte-macrophage colony-stimulating factor, enhancing the Th17 [57] and decreasing the Th2 differentiation [57, 58]. In rats on a high-carbohydrate diet, the meal, rich in stearic and palmitic acids, showed degenerative cartilage changes similar to OA cartilage. On the contrary, lauric acid diet group rats demonstrated decreased cartilage degeneration, increased hind paw withdrawal thresholds, grip strength, and decreased joint hypersensitivity effect of saturated fats on OA risk, with pain depending on the kind of FA present in the blood. In the diet, certain saturated FA types might contribute to prevent or slow the OA progression [51].

On the other hand, in the presence of lauric acid, the infectious production of vesicular stomatitis virus (VSV) was dose-dependently inhibited. Lauric acid also prevented that viral M protein bind to the host cell membrane. Thus, when VSV-infected animals were treated, the virus release was inhibited [59], meaning that the monocarboxylic acid chain's length has a

crucial role. Noteworthy is that only beta-hydroxy lauric acid significantly stimulated IL-6 production at 10 μg/mL compared to control (533.9 218.1 versus 438.3 219.6 pg/mL, P<0.05) in plasma of patients with chronic inflammatory diseases with/without insulin resistance [60].

Fermented shrimp paste

Shrimp shells are a good source of glucosamine, and the fermentation process breaks down the shell, thus making glucosamine more bioavailable. Glucosamine supplementation has shown to markedly decrease the risk of death from respiratory illnesses [61].

In Asian cuisines, a handful of sun-dried shrimps is commonly used as a flavor. In Thailand, kung haeng, dried shrimp, is extensively used in the cuisine with Thai herbs and chilies to create different types of paste for Thai curry and chili paste. Also, dried shrimp is applied to salads, for example, the green papaya salad called Som Tam. In the Vietnamese cuisine, dried shrimps (called tam kho) are included in soups, fried rice, toppings, congee and savory snack items. Also, dried shrimps are commonly used as snacks [32]. Clinical data have shown that glucosamine supplementation in the elderly significantly reduces the risk of mortality from respiratory diseases (HR 0.59; 95% CI 0.41-0.83) and cancer following the results of a USA cohort study [61].

Proposed mechanistic role of dietary bioactive compounds

Fruits, edible botanical oils, species, and vegetables are good sources of fiber, vitamins, and minerals, along with phytochemicals, like phenolic acids, flavonoids, terpenes and alkaloids, that are well-known to provide basic nutritional and other substantial health benefits. Compelling evidence has shown that various micronutrients present in fruits, oils, plant species and vegetables have remarkable antiviral, anti-inflammatory and immunomodulatory activities [8, 11, 12, 14, 18, 62, 63].

Some naturally-occurring bioactives are found to exhibit protective action against several respiratory viruses, among them curcumin, demethoxycurcumin, allicin, capsaicin, apigenin-7-glucoside, oleuropein, 6-gingerol, piperine, ellagic acid, epicatechin-gallate, ursolic acid, catechins, eugenol, isoeugenol, dithiolthiones, quercetin, cinnamic aldehyde, luteolin-7-glucoside, inositol hexaphosphate, maslinic acid, and D-limonene, as also some nutrients, such as vitamins C and E, lutein, folic acid, beta carotene, selenium, and dietary fiber [64]. These dietary agents have been reported to suppress the inflammatory processes and showed activity on Mpro/3CLpro (the key enzyme for coronavirus replication) [65, 66]. The role of integral elements widely consumed in Laotian, Cambodian, and Vietnamese diets in SARS CoV-2 prevention, through exerting anti-inflammatory, immunomodulatory, and antiviral effects (Figure 1).

The general structure of SARS CoV-2 has been pictured in Figure 2. Mpro/3CLpro is the key protease enzyme for coronavirus replication [66], and surface Spike (S) glycoprotein (S protein) is an important binding protein for the fusion of the virus with cell membrane via the cell receptor angiotensin-converting enzyme 2 (ACE2) [67]. The SARS-Cov-2 is easily transmitted because of the S protein on the surface of the virus that binds very efficiently to ACE2 on human cell surfaces [68, 69]. Therefore, Mpro/3CLpro and S protein are ideal targets for drug design and the development of antivirals. ACE-2 is the receptor for SARS CoV-2 as well as other coronaviruses and is expressed in type 2 alveolar epithelial cells and endothelium. The S-glycoprotein present on the surface of coronavirus binds to ACE-2 [70, 71]; this leads to a conformational change in the S-glycoprotein, allowing the proteolytic digestion by host cell proteases (TMPRSS2) ultimately leading to the internalization of the virion. The SARS CoV-2 transport is mediated by endosome [72]. The fusion of the virus membrane with the host endosomal membrane depends on the pH [73]. After uncoating the positive-sense, genomic ssRNA is translated into a polyprotein, which is cleaved into all structural and non-structural proteins. Replication occurs on the surface of

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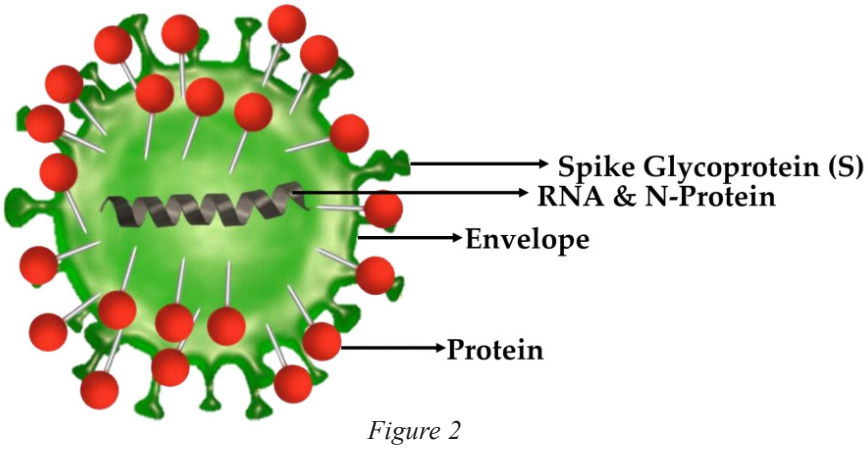

Figure 2
The general structure of SARS CoV-2

the endoplasmic reticulum in cytoplasmic viral factories. A dsRNA genome is synthesized from the genomic ssRNA(+). Virus assembly takes place at the endoplasmic reticulum; there, virions bud and are transported to the Golgi apparatus. In the Golgi, the prM protein is cleaved, and virion maturation takes place. Then, virions are released by exocytosis [70]. The probable mechanism of action of diet-derived bioactive compounds in SARS CoV-2 prevention is illustrated in Figure 3. It portrays the mode of entry of SARS CoV-2 and natural product drugs inhibiting viral entry and replication. The active phytoconstituents from dietary products may be functioning as inhibitors of fusion, uncoating, nucleic acid synthesis, integration, protease, and release.

Natural compounds, like hesperidin (*Citrus* fruit), rhoifolin (banana), and epigallocatechin gallate (green tea and onion), are found to exhibit better binding free energies with main protease (Mpro) and S protein of SARS-CoV-2 [65]. Cinnamon extract has shown anti-RNA viral effects [74]. Khaerunnisa et al. [21] found that quercetin (*Allium cepa, A. sativum, Capsicum annum*), luteolin-7-glucoside (olive, *C. annum*), demethoxycurcumin (*C. longa*), naringenin (citrus fruits), apigenin-7-glucoside (olive), oleuropein (olive), curcumin (*C. longa*), catechin and epicatechin-gallate (green tea) are amongst the most acclaimed phytocompounds in medicinal plants and spices that may act as potential inhibitors of SARS-CoV-2 Mpro. Maslinic acid isolated from olive oil was shown to be the top, binding candidate to target the active site of 3CLpro [75]. *Citrus spp.* and galangal have revealed the best potential as inhibitors of SARS-CoV-2 development [76]. *A. muricata* (soursop) has been found to inhibit the SARS-CoV-2 nsp12 polymerase activity [77]. *C. zeylanicum* essential oil showed potent inhibitory effects against influenza virus A1/Denver/1/57 (H1N1) [78], HSV1 [79]. These oils also exhibited potent antimicrobial effects against *S. aureus*, *E. coli*, *A. baumannii*, *P. aeruginosa* [80], *S. typhimurium* and *L. monocytogenes* [81] and also better antibiotic activity against *B. burgdorferi* [82]. The potent antiviral effect of eugenol, isolated from clove, against HSV-1 and HSV-2 [83], was also evident in herpes virus, delaying its development [84]. Thus, taken together, these findings are suggestive of the use of these dietary agents for preventive or prophylactic treatment against β-coronavirus infection, including SARS-CoV-2 (Figure 3).

Concluding remarks and upcoming perspectives

The review of literary sources on Vietnam, Cambodia, and Laos inhabitants' diet helps to determine which dietary factors could contribute reducing the severity of SARS-CoV-2 symptoms. The daily diet of the inhabitants in mentioned countries includes many salads, sauces, and dishes prepared using a large number of spices and aromatic herbs (Table 1), such as black and red pepper, citrus juice, especially the local type of lime - kaffir lime, banana lectin, coconut oil, soursop, turmeric, ginger, garlic and onion,

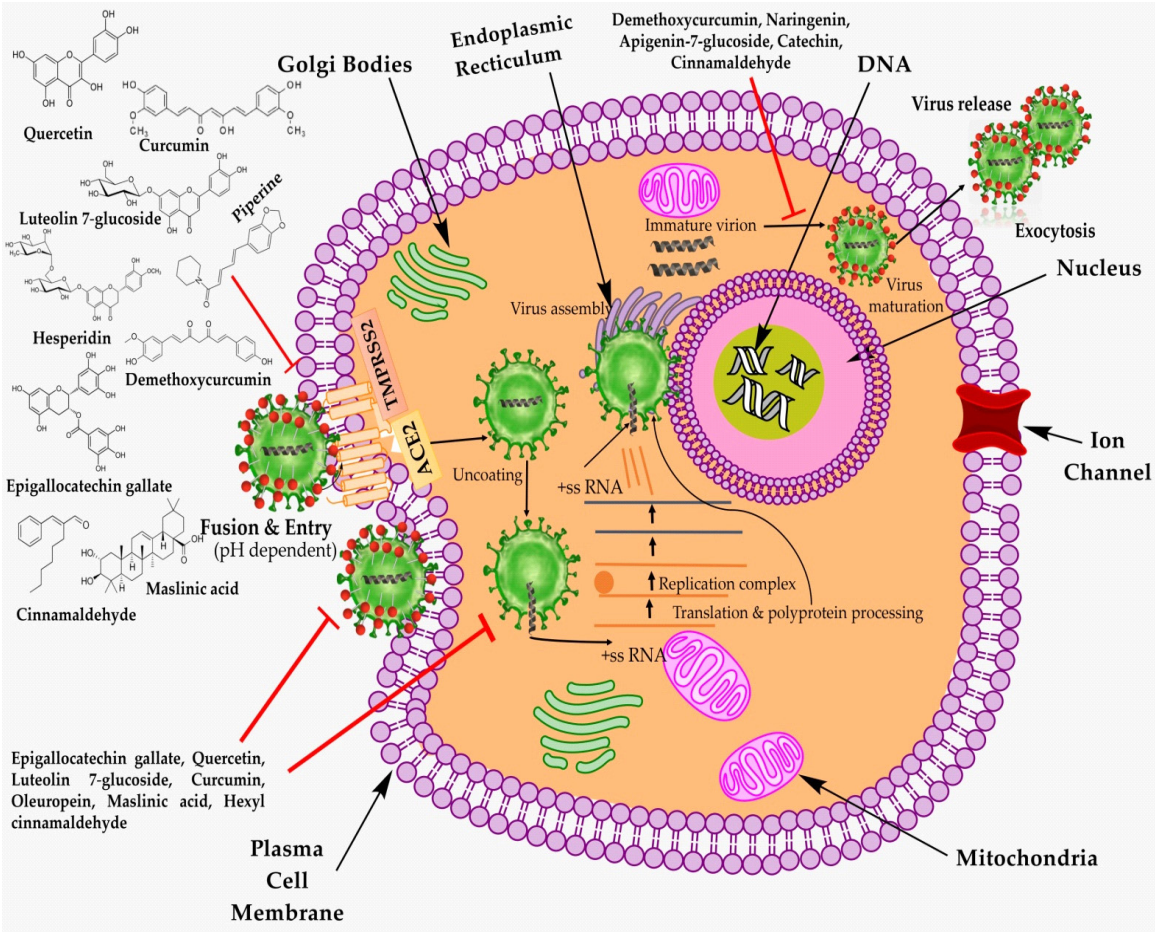

Figure 3
Probable mechanistic role of bioactive compounds in preventing SARS CoV-2

rosemary, clove and cinnamon, and fermented pasta. In fact, the use of these spicy herbs as natural therapeutic measures for several illnesses, including viral infections, has been reported since a long time ago. More in-depth studies have reported the bioactive compounds responsible for the observed effects, such as volatile aromatic molecules from terpenoids group, apigenin, linalool, ursolic acid, lauric acid, piperine, curcumin, among others that exhibit a broad spectrum of antiviral effects along with other biological activities. Therefore, all these items highlight the possibility of a significant contribution of local cuisine and diet into the impact on appropriate anti-inflammatory and immune-resistant mechanisms of the human population.

Conflict of interests

The authors declare no conflict of interest.

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Table 1

Medicinal plants and their pharmacological actions

Plant species	Family	Common name	Habitat and distribution	Used part(s)	Major constituents	Pharmacological effects, indications, uses	Refe-ren-ces
1	2	3	4	5	6	7	8
Allium cepa L.	*Alliaceae*	Onion	Central Asia, the Mediterranean; cultivated worldwide	bulbs	alliins (alkylcysteine sulphoxides): allylalliin and its γ-glutamyl conjugates; fructosans, saccharose; steroidal saponins; flavonoid spiraeoside	antimicrobial, antifungal, antiviral; lipid and blood pressure lowering, inhibits thrombocyte aggregation; antiallergic, antiasthmatic; loss of appetite, dyspeptic complaints, dehydration, ascariasis and other worm infestations, to stimulate gallbladder functions; fever, colds, tendency to infection, inflammation of the mouth and pharynx, pain, cough, bronchitis, asthma, angina; arteriosclerosis, hypertension, diabetes; the introduction of menstruation; fungal and bacterial infections; externally for insect bites, wounds, light burns, warts; culinary herb	85
Allium sativum L.	*Alliaceae*	Garlic	Central to southern Asia, Mediterranean; cultivation worldwide	bulbs; oil of bulbs	allyl sulphides: allicin, ajoene, diallylsulphide; S-allylcysteine; terpenoids: citral, geraniol, linalool; flavonoids: kaempferol, quercetin; fructosans; saponins; enzymes: allinase, peroxidases, myrosinase, catalases, superoxide dismutases, arginases, lipases	antibiotic, antibacterial, antifungal, antiviral, anthelmintic; expectorant, diaphoretic; antioxidant, hepatoprotective, antispasmodic, hypotensive, anti-thrombotic, fibrinolytic, hypolipidemic, anti-atherosclerotic; immunomodulatory, anticarcinogenic, antitumorigenic, chemopreventive; arteriosclerosis, raised levels of cholesterol, prevention of age-related vascular changes, hypertension; respiratory tract infections: common cold, recurrent colds, flu, fever, chronic bronchitis, respiratory catarrh, inflammatory respiratory conditions, whooping cough, bronchitic asthma; digestive disorders with flatulence and gastrointestinal spasms, constipation; menstrual pains, joint pain; diabetes; as a tonic; externally for corns, warts, calluses, otitis, muscle pain, neuralgia, arthritis, sciatica; ingredient in foods, culinary herb	4, 36, 37, 85, 86
Alpinia galanga (L.) Swarz	*Zingiberaceae*	Galangal, greater galangal	Indonesia, India, China, Malaysia, Sri Lanka, Arabic gulf areas, Egypt	rhizomes	phenylpropanoids: 1’S-1’-acetoxychavicol acetate (galangal acetate), 1’S-1’-acetoxyeugenol acetate, 1’-acetoxychavicol acetate, p-hydroxycinnamaldehyde, p-hydroxybenzaldehyde; curcuminoids: 1, 7-bis (4-hydroxyphenyl)-1, 4, 6-heptatrien-3-one, bisdemethoxycurcumin; monoterpenes: 1, 8-cineol, hydroxy-l, 8-cineol glucopyranosides, α-fenchyl acetate, β-farnesene, β-bisabolene, β-pinene; flavonoids: galangin; sterols: β-sitosteryl diglucoside, β-sitosteryl arabinoside	anti-inflammatory, antipyretic; emmenagogue, abortifacient, aphrodisiac; carminative, anti-ulcer; antimicrobial, anti-fungal; anti-tumor, antioxidant, anti-diabetic; immunomodulating; diabetes; rheumatism, rheumatic pains, chest pain; bronchitis, microbial infections, HIV, cholera, fever, coryza, inflammations; heart diseases; dyspepsia, gastritis, ulcers, chronic enteritis, burning of the liver; tumors; renal calculus, kidney disorders; otitis internal; eczema, pityriasis versicolor; culinary spice	27, 85, 87, 88
Annona muricata L.	*Annonaceae*	Soursop, graviola	Cultivated in Caribbean, Latin America, Southeast Asia, Pacific, Africa	fruits	annonaceous acetogenins; essential oil: β-caryophyllene, β-pinene, α-pinene, germacrene D, ρ-mentha-2,4(8)-diene, β-elemene, 1,8-cineole, linalool;alkaloids; megastigmanes; flavonol triglycosides; phenolics; cyclopeptides; sterols	antiviral, antimicrobial, insecticidal, antipediculicidal, molluscidal, larvicidal, antiparasitic, antimalarial; anticancer; anticonvulsant; anti-arthritic, anti-inflammatory, anti-nociceptive; immunomodulatory, antioxidant, astringent, gastroprotective, hepatoprotective, bilirubin-lowering, hypolipidemic, hypoglycemic; anxiolytic, antistress, antidepressant, antihypertensive; wound healing; cancer, parasitic infections, diarrhea, dysentery; arthritic pain, neuralgia, headaches, arthritis; fever, coughs, catarrh, malaria, rheumatism; skin diseases, skin rushes; to elevate a mother’s milk after childbirth; cystitis; diabetes; insomnia; ingredient in beverages and food products	46, 47, 89-91
Camellia sinensis (L.) Kuntze	*Theaceae*	Green tea, Chinese tea	China; cultivated in India, China, Sri Lanka, Japan, Indonesia, Turkey, Pakistan, Kenya, Malawi, Argentina	young downy leaves	methyl xanthines: caffeine (2.9-4.2%), theobromine, theophylline; catechins (10-25%): epigallocatechin gallate; flavonoids: quercetin, kaempferol, myricetin; volatile oil: linalool, 2-methyl-hept-2-en-6-on; theafolia saponins; inorganic salts: fluoride, potassium, aluminum	stimulant, diuretic, anti-depressive, antioxidant, anti-inflammatory; anti-tumor, cancer preventive; inhibition of cavity-associated bacteria growth, astringent, antidiarrheal, antibacterial; positively inotropic, promotes the secretion of gastric juices, glycolysis and lipolysis; dental caries and cancer prevention; stomach disorders, diarrhea, loss of appetite, hyperdipsia, nausea, vomiting; migraine, cardiac pain, fever; symptoms of fatigue, as a stimulant beverage	3, 22, 85

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Table 1(continuation)

Medicinal plants and their pharmacological actions

Plant species	Family	Common name	Habitat and distribution	Used part(s)	Major constituents	Pharmacological effects, indications, uses	References
1	2	3	4	5	6	7	8
Capsicum frutescens L., and some varieties of *C. annuum* L.	*Solanaceae*	Chili pepper, capsicum, Cayenne pepper, hot pepper, paprika	Mexico, Central America, Africa; widely cultivated	fruits; capsaicin, pungent fruit oleo-resin	capsinoids: capsaicin, dihydrocapsaicin, capsiate, dihydrocapsiate, carotenoids (0.3-0.8%): capsanthin, ?-carotene, violaxanthine; volatile oil: 2-methoxy-3-isobutyl pyrazine, capsiamide; flavonoids: apiin, luteolin-7-O-glucoside; steroid saponins: capsicidine	local analgesic, hyperemic, counterirritant; antimicrobial, detoxicant, antioxidant, anti-inflammatory, gastroprotective, antispasmodic, carminative; antineoplastic; stimulant, diaphoretic; thrombolytic; gastrointestinal disorders, colic, flatulent dyspepsia without inflammation, cholera, anorexia nervosa, seasickness; insufficiency of peripheral circulation, prevention of arteriosclerosis, stroke, heart disease; externally muscular tensions in shoulder, arm and spine, neuralgia, chronic lumbago, rheumatism, edema; coughs, frostbite, chilblains; as a gargle for hoarseness, sore and infected throats, chronic laryngitis; postherpetic neuralgia, painful diabetic neuropathy, osteoarthritis, pruritus, gout, arthritis, sciatica; spice, food flavoring	19, 85, 86
Cinnamomum zeylanicum Blume (*C. verum* J.Presl)	*Lauraceae*	Cinnamon, Ceylon cinnamon	Sri Lanka, southwest India, the Seechelles, Madagascar	bark; cinnamon oil of the inner bark	volatile oil (up to 4%): cinnamaldehyde, eugenol, cinnamylacetate, cinnamyl alcohol, o-methoxy cinnamaldehyde, cinnamic acid; diterpenes: cinnzeylanol, cinnzeylanin; oligomeric proanthocyanidins; mucilages	antibacterial, fungistatic, anthelmintic, insecticide; promotes motility, increases gastric secretions, orexigenic, carminative, antispasmodic, astringent, antidiarrheal; anti-inflammatory; loss of appetite, dyspeptic complaints, intestinal colic, flatulent colic, diarrhea, infantile diarrhea, worm infestation, nausea, vomiting; fever, chills, common cold, influenza; toothache, halitosis; externally for cleaning wounds; spice in cooking, natural source of food flavoring	19, 85, 86
Citrus hystrix	*Rutaceae*	Kaffir lime, Mauritius papeda, makrut lime	Southern China, tropical South-east Asia	fruits, leaves	volatile oil: limonene, sabinene, citronellal, α-terpineol, terpinen-4-ol, α-pinene, β-pinene, α-terpinene, γ-terpinene; pyranoflavones; coumarins; quinolinone derivatives	antibacterial; antioxidant, cardioprotective, hepatoprotective, anti-inflammatory, cytotoxic; antidiabetic, ?-amylase inhibitory; acetylcholinesterase inhibitory; essential oil: antioxidant, antibacterial, antileukemic, antitussive; insecticidal, repellant; headache, flu, fever, sore throat; digestive stimulant, abdominal pains, diarrhea in infants, bad breath and indigestion; hypertension, blood purifier; the fruit juice in softening the skin; a food, an ingredient in foods, in cooking for flavoring, fragrance; essential oil in aromatherapy	38-40, 92
Cocos nucifera L.	*Arecaceae*	Coconut, coconut palm	Pacific regions	oil from the dried solid part of endosperm	fatty acids: lauric (45-53%); myristic, palmitic, caprylic, caproic; deltaoctalactone	dietetic; cartilage protection, antimicrobial, antiviral, anti-inflammatory (lauric acid); poorly healing wounds and skin infections; colds and throat inflammation, coughs, bronchitis; tooth decay; dysuria; osteoarthritis; to stop hair from turning gray; food ingredient, edible oil	51, 52, 57, 58, 85
Curcuma longa L. (*C. domestica* Val.)	*Zingiberaceae*	Turmeric	India; cultivated in India and other tropical regions of southeast Asia	rhizomes	curcuminoids: curcumin, mono- and bisdemethoxycurcumin; an essential oil (3–5%), containing 60% turmerones; polysaccharides: starch, glycans, ukonans	hepatoprotective, hypocholesterolemic, anti-inflammatory, anti-ulcer, digestive, spasmolytic; hypoglycemic, free radical scavenging, antioxidant, antitumoral; antibacterial, antiseptic, antiprotozoal; dyspeptic complaints, loss of appetite, diarrhea; inflammatory conditions (malignant diseases, arthritis, allergies, Alzheimer's disease, bronchitis, colds, intermittent fever, kidney inflammation, cystitis, conjunctivitis); immunostimulant, general tonic, liver disorders, blood purifier, nose bleeds, blood rushes, amenorrhea, heat stroke; chest infections; headaches, pains in the chest, ribs, upper abdomen, liver and stomach; stomach complaints, flatulence, colic, constipation, worms, ringworm infestation, vomiting with bleeding; wounds, insect bites, edema, leprosy, skin ulcers, itching; externally for bruising, leech bites, festering eye infections, inflammation of the oral mucosa, inflammatory skin conditions and infected wounds; spice	3, 33, 34, 85
Elaeis guineensis Jacq	*Arecaceae*	Oil palm, African oil palm	West Africa, Brazil and other tropical countries	oil from fruit mesocarp	fatty acids: lauric, myristic, palmitic, oleic, linoleic; carotenoids: β-carotene; phospholipids	dietetic; antimicrobial; antidiabetic; anodyne, anti-inflammatory, antioxidant, hypocholesterolemic, anti-clotting, antidotal, aphrodisiac, diuretic; anticancer; cartilage protection, antimicrobial, antiviral, anti-inflammatory (lauric acid); headaches, pains, rheumatism, osteoarthritis; cardiovascular diseases, arterial thrombosis, atherosclerosis; skin infections; diarrhea and dysentery in infants; food ingredient, edible oil	51, 52, 57, 58, 85, 93

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Table 1

Medicinal plants and their pharmacological actions

Plant species	Family	Common name	Habitat and distribution	Used part(s)	Major constituents	Pharmacological effects, indications, uses	Refe-ren-ces
1	2	3	4	5	6	7	8
Musa paradisiaca L.	*Musaceae*	Banana, Plantain banana	tropical areas	unripened fruit pulp	polysaccharides: starch (20%); protein (1%); potassium; ascorbic acid; amines: serotonin, tyramine, dopamine, noradrenaline; fruit acids: malic, citric; aromatic substances: isopentenyl acetate; banana lectin	antiulcerogenic, cholesterol-reducing; immunomodulatory, antiproliferative (banana lectin); dyspepsia, diarrhea, worm disease, gastrointestinal complaints; diabetes, scurvy, hypertension, dysuria, kidney disease, gout; severe thirst, bronchitis, pharyngalgia; scabies, itching; source of potassium; an ingredient in foods	49, 50
Ocimum basilicum L.	*Lamiaceae*	Thai basil, sweet basil	Originated in India, Afghanistan, Pakistan; cultivated worldwide	fresh or dried herb; oil from the dried aerial parts	volatile oil: chavicol methyl ether (estragole), linalool, eugenol; caffeic acid derivatives; flavonoids: apigenin; triterpenes: ursolic acid	antimicrobial, antiviral, anti-inflammatory, immunomodulatory, hemostyptic; supportive therapy for feelings of fullness and flatulence, stimulation of appetite and digestion, anorexia; gum ulcers; as a diuretic, disturbances of renal function; earaches, rheumatoid arthritis, itching, skin diseases; upper respiratory tract infections; amenorrhea, dysmenorrhea, malaria and other febrile disorders (herb); wounds, rheumatic complaints, colds, chills, contusions, joint pains, depression (oil); ingredient in foods	42-45
Piper nigrum L.	*Piperaceae*	Black pepper	wild in Southeast and South Asia; cultivated in tropical Asia and the Caribbean	berries, freed from the pericarp; dried fruit	alkaloid piperine and acid amides (pungent substances): piperylin, piperolein A and B; volatile oil (1.2-2.6%): sabinene, limonene, caryophyllene, α- and β-pinene, 3-carene; fatty oil; polysaccharides	anti-inflammatory, anti-allergic, antimicrobial, insecticidal; stimulates the thermal receptors, digestive, increases secretion of saliva and gastric mucous, improves liver and metabolic functions; gastric disorders, vomiting, diarrhea, dysentery, dyspepsia, flatulence, hemorrhoids; neuralgia, arthritis, scabies; asthma, fever, skin damage; coughs, catarrh, hiccoughs; urethral discharge; enhancing drug absorption; ingredient in foods	48, 85
Rosmarinus officinalis L.	*Lamiaceae*	Rosemary	Mediterranean region, Portugal; cultivated in the Crimean Peninsula, Transcaucasus, Central Asia, India, Southeast Asia, South Africa, Australia, the U.S.	leaves; twig tips; oil pf leaves and leafy stems	caffeic acid derivatives: rosmarinic acid; volatile oil (1.0 to 2.5%): 1,8-cineole, α-pinene, camphor, camphene, borneol, bornyl acetate, β-caryophyllene, p-cymene, limonene, linalool, myrcene, α-terpineol, verbenone; diterpenes: carnosolic acid, isorosmanol, rosmadial, rosmaridiphenol, rosmariquinone; flavonoids: cirsimarin, diosmin, hesperidin, homoplantiginin, phegopolin;triterpenes: oleanolic acid, ursolic acid and their 3-acetyl esters	antimicrobial, antiviral; carminative, spasmolytic, choleretic, liver-protective, anti-inflammatory, diuretic; anti-convulsive, thymoleptic, sedative; antimutagenic, tumor-inhibiting; topically: rubefacient, mild analgesic, parasiticide; blood pressure problems, dyspeptic complaints, loss of appetite; memory improvement, headaches, migraine, states of exhaustion, dizziness; dysmenorrhea, amenorrhea, oligomenorrhea; externally: rheumatism, skin irritating, myalgia, intercostal neuralgia, sciatica, hypotonic circulatory disorders, poorly healing wounds, eczema; an analgesic for injuries of the mouth and throat; flavoring agent in foods	85, 86
Syzygium aromaticum (L.) Merril. Et M. Perry (*Eugenia caryophyllata* Thunb)	*Myrtaceae*	Clove, cloves	Indonesia (Molucca Islands); cultivated in Tanzania, Madagascar, Brazil and other tropical areas	whole flower buds; clove oil	essential oil (15–21%): eugenol (85–90%), acetyl eugenol, α- and β-caryophyllene, methyl salicylate; flavonoids: astragalin, isoquercitrin, hyperoside; tannins: eugenin; triterpenes: oleanolic acid, crataegolic acid; steroids: beta-sitosterol	dental (local) anesthetic, dental analgesic, anti-inflammatory, counter-irritant; antiseptic, antibacterial, antifungal, antiviral; antihistaminic; antispasmodic, carminative, anti-emetic, anthelmintic; immunomodulatory; short-term symptomatic relief for dental pain, inflammation of the mucous membranes of mouth and throat, colds and headaches, halitosis, deodorizer, anti-inflammatory agent; eye diseases; internally for stomach ulcers, flatulence, colic, gastropathy, anorexia; natural source of food flavoring, culinary spice in cooking	24, 85, 86
Zingiber officinale Roscoe	*Zingiberaceae*	Ginger	indigenous to south-eastern Asia; cultivated in U.S., Jamaica, Nigeria, south and south-eastern Asia, China, other tropical regions	rhizomes	volatile oil (1–3%): zingiberene, arcurcumene, zingiberol, geranial, neral, β-bisabolene; phenylpropanoids: gingerols, gingerdiols, gingerdiones, dihydrogingerdiones, zingerone, shogaols; diarylheptanoids: gingerenone A and B; starch; lipids	antiemetic, anti-inflammatory, anti-ulcer, carminative, expectorant, diaphoretic, hepatoprotective, spasmolytic, antiflatulent; hypolipidemic, hypoglycemic, positively inotropic, antiplatelet aggregation, antithrombotic; antitussive, warming, immune system stimulation; antioxidant, free radical scavenging, anticancer; promotes secretion of saliva, gastric juices and bile; loss of appetite, morning and motion (travel) sickness, vertigo, nausea, vomiting; dyspeptic complaints, colic, flatulent intestinal colic, anorexia, diarrhea, abdominal distension and pyrexia; cough, colds, pharyngitis, shortness of breath; rheumatism, osteoarthritis, rheumatoid arthritis, joint muscle pain; migraine headaches; natural source of food flavoring, culinary spice	19, 27, 30, 31, 85, 86

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