Micro Nano Bio Aspects

https://www.mnba-journal.com

Online ISSN: 2980-8081

Novel formulations of Kaempferol and its monosaccharide derivatives for healing cancers and microbial infections

Naser Karimi[1*] and Mehdi Valizadeh[2]

[1]*Department of Biology, Faculty of Science, Razi University, Kermanshah, Iran*

[2]*Unit of Genomics Research, Digestive Diseases Research Center, Ardabil University of Medical Sciences, Ardabil, Iran*

ARTICLE INFO

Mini-review paper

Article history:
Received: 09 June 2023
Revised: 08 Aug 2023
Accepted: 09 Aug 2023
ePublished: 11 Aug 2023

Keywords:
Plant-derived metabolite,
Kaempferol-3-glucoside,
Kaempferol 7-O-glucoside,
Therapeutic limitation,
Nanocarriers

ABSTRACT

Natural compounds isolated from plant species have a potential pharmacological capability and is now regarded to be an alternative therapeutic agent. Flavonoid metabolites have exhibited significant antioxidant, anti-inflammatory, antimicrobial, and anticancer properties. Kaempferol and its monosaccharide derivatives such as kaempferol-3-glucoside and kaempferol 7-O-glucoside as a well-studied bioactive compound have shown remarkable therapeutic activities. As a major therapeutic limitation, this plant-derived metabolite is soluble in ethanol and slightly soluble in aqueous solvents. This property can hinder the clinical application of kaempferol, as recent studies have tried to discovery effective micro and nano formations. In this way, this mini-review has discussed efficacy of these novel formulations in recent years. This study has shown micro and nanocarriers can improve bioavailability property of kaempferol and its monosaccharide derivative derivatives.

DOI: https://doi.org/10.22034/mnba.2023.401346.1036

Introduction

In the recent years, bioactive compounds have achieved significant achievements in the treatment of various microbial infections and cancers [1]. This inspired scientists to continuously evaluate new formulations of bioactive agents isolated from various natural sources, specifically medical plant species [2-4]. The therapeutic application of natural compounds has gained a lot of attention because of acceptable biocompatibility and biodegradability of these bioactive compounds in physiological conditions [5-7]. Kaempferol (3,4′,5,7-tetrahydroxyflavone ($C_{15}H_{10}O_6$)) is a natural flavonol related to flavonoid group (Figure 1), which can be isolated from variety of plant species such as *Capparis spinosa* [8], *Crocus sativus* [9], *Eruca vesicaria* [10], *Brassica oleracea* [11], *Brassica juncea* [12], *Zingiber officinale* [13], *Phaseolus vulgaris* [14], and *Brassica rapa* [15]. Furthermore, this polyphenol compound is opulently found in fruits, vegetables and medicinal plant-derived beverages [15]. It has been reported that kampferol has some health benefits including antioxidant, anti-inflammatory, antimicrobial, lipolytic, anti-hypertensive, anti-diabetic and anticancer activities [16, 17].

Kaempferol biosynthesis is polyphenol compounds which is structurally composed of diphenylpropane. This bioactive metabolite synthesized through condensation process by chalcone synthase that combine three molecules of malonyl-CoA and one molecule of 4-coumaroyl-CoA and producing naringenin chalcone. Naringenin chalcone was converted into naringenin flavanone and thereby dihydrokaempferol produced. In the last step, flavonol synthase make double bound in C2–C3 of dihydrokaempferol and producing kaempferol [18].

Cancer-related activities and processes including cell cycle, apoptosis, oxidative stress, proliferation, angiogenesis, and metastasis can be affected by kaempferol [19]. Kaempferol acts as bioactive compound and effect on a range of intracellular as well as extracellular targets involved in the cell signaling

*Corresponding author. E-mail: nkarimi@razi.ac.ir

pathways that in turn are known to regulate the hallmarks of cancer growth progressions like apoptosis, cell cycle, invasion or metastasis, angiogenesis and inflammation. This herbal material is soluble in dimethyl sulfoxide (DMSO), ethanol, and ethers and poorly soluble aqueous solvents [20]. Therefore, new strategies such as polytherapy or combination therapy and nono-formulations can improve the half-life and healing activities of kaempferol. On the other hand, the issue of the poor bioavailability of kaempferol has been resolved by nanotechnology. In this way, this mini-review has tried to cover these aspects of formulations based on recent studies.

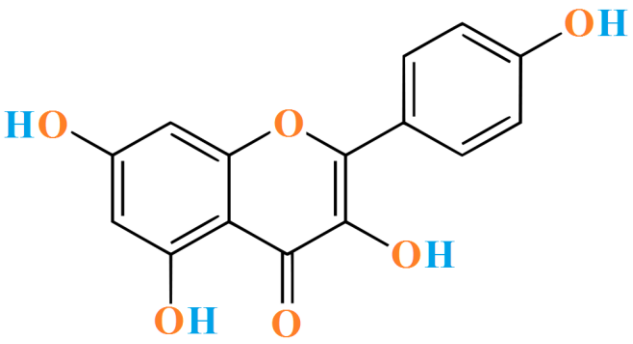

Fig. 1. Chemical structure of kaempferol.

Anticancer effects

Plant-derived flavonoids are regarded natural bioactive compounds and have been widely used as treatments different types of cancers, such as bladder cancer, bone cancer, breast cancer, cervical cancer, colon cancer, gastric cancer, endometrial cancer, liver cancer, lung cancer, ovarian cancer, nervous system cancer, pancreatic cancer, prostate cancer, skin cancer, nervous system cancer and leukemia [21]. Kaempferol can modulate cell signaling pathways and various cancer-related processes including angiogenesis, proliferation, tumor suppressor gene, oxidative stress, cell cycle, apoptosis, autophagy and metastasis [22, 23]. Cell cycle arrest can be resulted from kaempferol treatment by increasing and decreasing of p53 and c-Myc (A multifunctional transcription factor), respectively [24]. In the case of angiogenesis, kaempferol reduce a level of HIF-1 (hypoxia inducible factor-1) VEGF (vascular endothelial growth factor), and ESRRA (estrogen related receptor alpha) [25]. Breast cancer is introduced as one of the deadliest cancer in women, which there are conventional methods including radiation, surgery, and medicine (anthracyclines, anti-estrogen drugs, aromatase inhibitors, monoclonal antibody drugs, and anti-angiogenesis drugs) therapy for treatment it [26]. Three main ways involving blocking the growth (at G2/M stage via downregulation of CDK1), inducing the apoptosis (by induction of the cleavage of poly-ADP ribose polymerase (PARP) expression), and inhibiting migration and invasion (through inhibition of triclosan-induced epithelial-mesenchymal transition (EMT) and metastatic proteins) of breast cancer cells have been indicated for anticancer mechanisms of kaempferol [27]. In a comparative study, kaempferol showed higher antitumor activity than kaempferol-7-O-glucoside, kaempferol-3-O-rhamnoside, and kaempferol-3-O-rutinoside. In addition, kaempferol promoted caspase-dependent apoptosis and inhibited AMPK and AKT signaling pathways in liver cancer cells [28]. In other nano-formualtions, metal or metal oxide nanoparticles have been used to loading various natural compounds [29, 30]. As an example, kaempferol-coated AgNPs showed remarkable anticancer effects on liver cancer (HepG2) cells through cell cycle arrest and oxidative stress-mediated apoptosis [31].

Antioxidant and anti-inflammatory effects

Reactive oxygen species (ROS) such as free radicals of superoxide (O_2^{-*}) and hydroxyl radical (OH^*) or nonradical species, such as hydrogen peroxide (H_2O_2) in prolonged oxidative stress can lead to mutations and uncontrolled cell division [32]. Acting on the Nrf2-Keap1 complex is the main antioxidant mechanism of kaempferol. In this regard, the level of Nrf2 is augmented by this polyphenol antioxidant (Figure 2) [19]. Kaempferol plays a promising role in combatting cancer by modulating the Nrf2 transcriptional pathway and decrease cell redox homeostasis [33]. Kaempferol and three glycoside derivatives including kaempferol-3-O-rutinoside, kaempferol-7-O-glucoside, and kaempferol-3-O-rhamnoside blocked the proliferation of activated T cells in a dose and time-dependent manner. Moreover, kaempferol hindered lipopolysaccharide (LPS)-induced ROS production in a concentration-dependent manner [28].

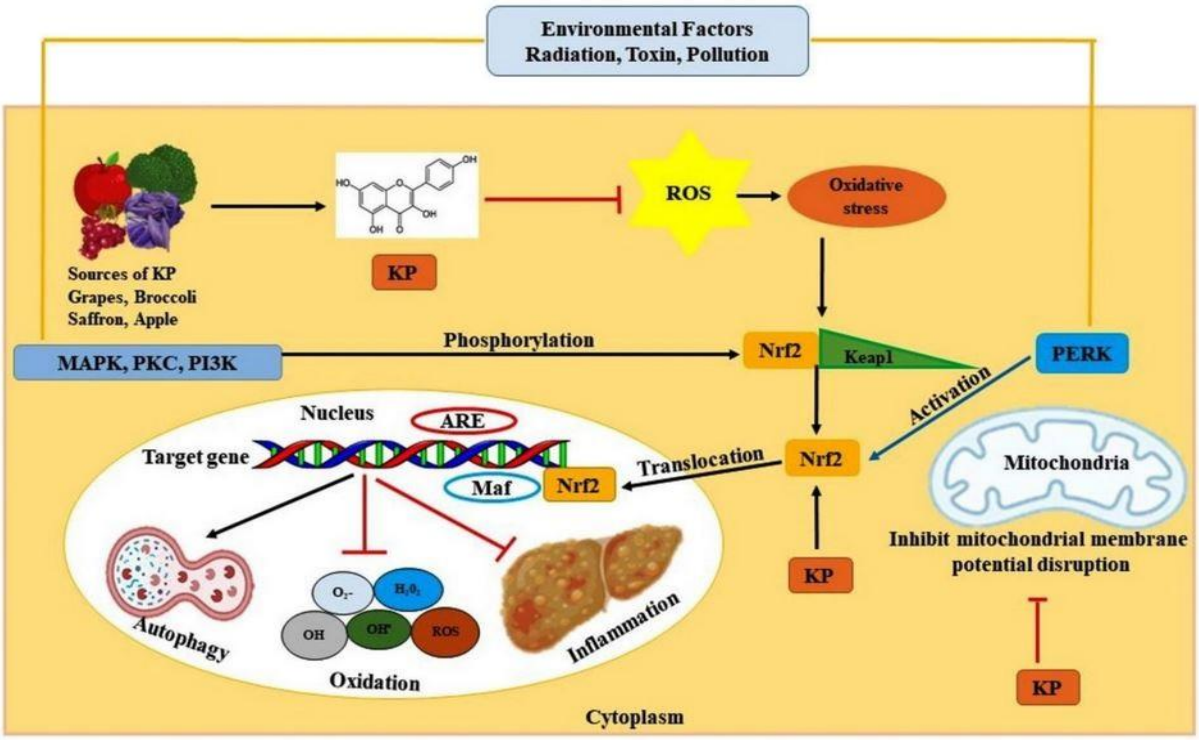

Fig. 2. Antioxidant effects of kaempferol (KP) via KP via Nrf2-Keap1 pathway. Nrf2 (nuclear factor erythroid 2 related factors 2), Keap1 (Kelch-like ECH-associated protein 1), Maf (musculoaponeurotic fibrosarcoma) transcription factor, ARE (the antioxidant response element sequence) (adopted and modified from [19]).

Antimicrobial effects

In the case of implanted medical devices, the most common bacterial infections are resulted from the biofilm formation on surfaces by *Staphylococcus aureus*. Kaempferol at a concentration of 64 µg/mL (at sub-inhibitory concentration) inhibited biofilm formation of bacteria by 80%. Reduction in fibrous protrusions on the surface of *S. aureus* was found as the major antibiofilm mechanism of kaempferol [34]. Encapsulation or loading of therapeutic agents including natural compounds or drugs by nanomaterials such as liposomes, polymeric nanoparticles, and metallic nanoparticles can promote healing processes [35, 36]. In the case of polymeric nanomaterials, cellulose and chitosan are two main biocompatible polysaccharides applicable to a wide range of therapeutic nano-formulations [37]. Chitosan as a polycation linear polysaccharide (β-(1→4)-linked D-glucosamine and N-acetyl-D-glucosamine) can be isolated from the chitin shells of shrimp or other crustaceans [38]. Chitosan/sodium tripolyphosphate NPs were produced by the electrostatic self-assembly method. Quorum sensing *Chromobacterium violaceum* CV026 bacteria was inhibited by kaemperol loaded on chitosan/sodium tripolyphosphate nanoparticles with a diameter of 192.27 nm [39]. Nanotechnology has obtained high attention owing to the unique physicochemical, biological, and biomedical properties of organic and inorganic nanomaterials [40]. Among the inorganic nanomaterials, silver (Ag) NPs have been employed in various fields, such as catalysis, biosensors, anticancer, and antimicrobials agents. These NPs have shown antimicrobial activity in a broad-spectrum against bacteria, fungi, parasites, and viruses [41]. Conjugation of AgNPs with kaempferol and hydrocortisone resulted in NPs with spherical shape in a size range of 10–30 nm. These NPs showed remarkable stability and strong antibacterial activity against *Bacillus subtilis*, *Escherichia coli*, and *Staphylococcus aureus*. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values of these NPs against *E. coli* were 62.5 and 125 µg/mL, respectively. Production of ROS and lipid peroxidation were indicated the main antibacterial mechanisms of AgNPs-kaempferol-hydrocortisone [42].

Conclusions

The main barrier for the clinical application of kaempferol is its low solubility in aqueous solutions. Two approaches encompassing the combined therapy

and novel biocompatible micro and nano-formulations can reduce this limitation. Both organic and inorganic nanomaterials have been employed to obtaining acceptable therapeutic outcomes. For example, nanoformulation of kaempferol using organic polymers such as chitosan has demonstrated a significant anti-quorum sensing activity against *C. violaceum*. In a comparative way, kaempferol-3-O-rutinoside, kaempferol-7-O-glucoside, and kaempferol-3-O-rhamnoside showed poor anticancer, anti-inflammatory, and antioxidant activities than kaempferol. The major antibiofilm mechanism of kaempferol was reduction in fibrous protrusions on the surface of *S. aureus*. For nanoformulations of AgNPs-kaempferol-hydrocortisone, production of ROS and lipid peroxidation were the main antibacterial mechanisms.

Study Highlights

- The main barrier for the clinical application of kaempferol is its low solubility in aqueous solutions.
- Nanoformulation of kaempferol using organic polymers such as chitosan has demonstrated a significant anti-quorum sensing activity against *C. violaceum*.
- Kaempferol-3-O-rutinoside, kaempferol-7-O-glucoside, and kaempferol-3-O-rhamnoside showed poor anticancer, anti-inflammatory, and antioxidant activities compared to kaempferol.
- The major antibiofilm mechanism of kaempferol was reduction in fibrous protrusions on the surface of *S. aureus*.
- Nanoformulations of AgNPs-kaempferol-hydrocortisone, production of ROS and lipid peroxidation were the main antibacterial mechanisms.

Abbreviations

ARE: Antioxidant response element sequence
c-Myc: A multifunctional transcription factor
EMT: Epithelial-mesenchymal transition
ESRRA: Estrogen related receptor alpha
HIF-1: Hypoxia inducible factor-1
Keap1: Kelch-like ECH-associated protein 1
LPS: Lipopolysaccharide
Maf: Musculoaponeurotic fibrosarcoma
MBC: Minimum bactericidal concentration
MIC: Minimum inhibitory concentration
Nrf2: Nuclear factor erythroid 2 related factors 2
PARP: Poly-ADP ribose polymerase
ROS: Reactive oxygen species
VEGF: Vascular endothelial growth factor
AMPK: AMP-activated protein kinase

Funding

This work was not supported by any institutes.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

This article does not contain any studies with animals or human participants performed by any of the authors.

Author Contributions

All authors: conceptualization, preparing the first draft, and editing.

Acknowledgments

Declared none.

References

1. Aljelehawy QHA, Mohammadi S, Mohamadian E, Raji Mal Allah O, Mirzaei A, Ghahremanlou M. Antimicrobial, anticancer, antidiabetic, antineurodegenerative, and antirheumatic activities of thymol: clarification of mechanisms. Micro Nano Bio Aspects. 2023;2(1):1-7. doi:https://doi.org/10.22034/mnba.2023.381107.1019
2. Ahmadi S, Ahmadi G, Ahmadi H. A review on antifungal and antibacterial activities of some medicinal plants. Micro Nano Bio Aspects. 2022;1(1):10-7. doi:https://doi.org/10.22034/mnba.2022.150563
3. Chavda VP, Patel AB, Mistry KJ, Suthar SF, Wu Z-X, Chen Z-S, et al. Nano-Drug Delivery Systems Entrapping Natural Bioactive Compounds for Cancer: Recent Progress and Future Challenges. Frontiers in Oncology. 2022;12. doi:https://doi.org/10.3389/fonc.2022.867655
4. Alavi M, Yarani R, Sreedharan M, Thomas S. Micro and nanoformulations of catechins for therapeutic applications: recent advances and challenges. Micro Nano Bio Aspects. 2023;2(1):8-19. doi:https://doi.org/10.22034/mnba.2023.382922.1021
5. Aljelehawy Q, Maroufi Y, Javid H, Mohammadi MR, Raji Mal Allah O, Taheri SV, et al. Anticancer, antineurodegenerative, antimicrobial, and antidiabetic activities of carvacrol: recent advances and limitations

for effective formulations. Nano Micro Biosystems. 2023;2(1):1-10. doi:https://doi.org/10.22034/nmbj.2023.380207.1009
6. Do NHN, Truong QT, Le PK, Ha AC. Recent developments in chitosan hydrogels carrying natural bioactive compounds. Carbohydrate Polymers. 2022;294:119726. doi:https://doi.org/10.1016/j.carbpol.2022.119726
7. Aljelehawy Q, Mal Allah OR, Sourazur G. Physicochemical properties, medicinal chemistry, toxicity, and absorption of quercetin and its interaction with spike glycoprotein of SARS-CoV-2: Molecular docking. Nano Micro Biosystems. 2022;1(1):32-9. doi:https://doi.org/10.22034/nmbj.2022.163207
8. Shahrajabian MH, Sun W, Cheng Q. Plant of the Millennium, Caper (Capparis spinosa L.), chemical composition and medicinal uses. Bulletin of the National Research Centre. 2021;45(1):131. doi:https://doi.org/10.1186/s42269-021-00592-0
9. Ghasemzadeh Rahbardar M, Hosseinzadeh H. A review of how the saffron (Crocus sativus) petal and its main constituents interact with the Nrf2 and NF-κB signaling pathways. Naunyn-Schmiedeberg's Archives of Pharmacology. 2023. doi:https://doi.org/10.1007/s00210-023-02487-5
10. Bell L, Wagstaff C. Rocket science: A review of phytochemical & health-related research in Eruca & Diplotaxis species. Food Chemistry: X. 2019;1:100002. doi:https://doi.org/10.1016/j.fochx.2018.100002
11. Golli R, Thummaneni C, Vangalapati M. Green synthesis and characterization for the extraction of kaempferol from Brassica oleracea var. italica – Antibacterial activity. Materials Today: Proceedings. 2022;62:3457-61. doi:https://doi.org/10.1016/j.matpr.2022.04.280
12. Torrijos R, Righetti L, Cirlini M, Calani L, Mañes J, Meca G, et al. Phytochemical profiling of volatile and bioactive compounds in yellow mustard (Sinapis alba) and oriental mustard (Brassica juncea) seed flour and bran. LWT. 2023;173:114221. doi:https://doi.org/10.1016/j.lwt.2022.114221
13. Özcan MM. The effect of ginger (Zingiber officinale) powders at different concentrations on bioactive compounds, antioxidant activity, phenolic constituents, nutrients and sensory characteristics of wheat bread. International Journal of Gastronomy and Food Science. 2022;28:100532. doi:https://doi.org/10.1016/j.ijgfs.2022.100532
14. Fuentes E, Rodríguez L, Méndez D, Alarcón-Espósito J, Nina N, Burgos-Edwards A, et al. Inhibition of platelet aggregation by extracts and compounds from the leaves of Chilean bean landraces (Phaseolus vulgaris L.). Journal of Functional Foods. 2023;100:105388. doi:https://doi.org/10.1016/j.jff.2022.105388
15. Managa MG, Remize F, Garcia C, Sivakumar D. Effect of Moist Cooking Blanching on Colour, Phenolic Metabolites and Glucosinolate Content in Chinese Cabbage (Brassica rapa L. subsp. chinensis). Foods. 2019;8(9):399. doi:https://doi.org/10.3390/foods8090399
16. Kaur S, Kumar A, Thakur S, Kumar K, Sharma R, Sharma A, et al. Antioxidant, Antiproliferative and Apoptosis-Inducing Efficacy of Fractions from Cassia fistula L. Leaves. Antioxidants. 2020;9(2):173. doi:https://doi.org/10.3390/antiox9020173
17. Mohammed HA, Al-Omar MS, Khan RA, Mohammed SAA, Qureshi KA, Abbas MM, et al. Chemical Profile, Antioxidant, Antimicrobial, and Anticancer Activities of the Water-Ethanol Extract of Pulicaria undulata Growing in the Oasis of Central Saudi Arabian Desert. Plants. 2021;10(9):1811. doi:https://doi.org/10.3390/plants10091811
18. Alam W, Khan H, Shah MA, Cauli O, Saso L. Kaempferol as a Dietary Anti-Inflammatory Agent: Current Therapeutic Standing. Molecules. 2020;25(18):4073. doi:https://doi.org/10.3390/molecules25184073
19. Sharma N, Biswas S, Al-Dayan N, Alhegaili AS, Sarwat M. Antioxidant Role of Kaempferol in Prevention of Hepatocellular Carcinoma. Antioxidants. 2021;10(9):1419. doi:https://doi.org/10.3390/antiox10091419
20. Cid-Ortega S, Monroy-Rivera JA. Extraction of Kaempferol and Its Glycosides Using Supercritical Fluids from Plant Sources: A Review. Food Technology and Biotechnology. 2018;56(4):480-93. doi:https://doi.org/10.17113/ftb.56.04.18.5870
21. Song L, Xiong P, Zhang W, Hu H, Tang S, Jia B, et al. Mechanism of Citri Reticulatae Pericarpium as an Anticancer Agent from the Perspective of Flavonoids: A Review. Molecules. 2022;27(17):5622. doi:https://doi.org/10.3390/molecules27175622
22. Qattan MY, Khan MI, Alharbi SH, Verma AK, Al-Saeed FA, Abduallah AM, et al. Therapeutic Importance of Kaempferol in the Treatment of Cancer through the Modulation of Cell Signalling Pathways. Molecules. 2022;27(24):8864. doi:https://doi.org/10.3390/molecules27248864
23. Ashrafizadeh M, Tavakol S, Ahmadi Z, Roomiani S, Mohammadinejad R, Samarghandian S. Therapeutic effects of kaempferol affecting autophagy and endoplasmic reticulum stress. Phytotherapy Research. 2020;34(5):911-23. doi:https://doi.org/10.1002/ptr.6577
24. Kashafi E, Moradzadeh M, Mohamadkhani A, Erfanian S. Kaempferol increases apoptosis in human cervical cancer HeLa cells via PI3K/AKT and telomerase pathways. Biomedicine and Pharmacotherapy. 2017;89:573-7. doi:https://doi.org/10.1016/j.biopha.2017.02.061
25. Shanmugam MK, Kannaiyan R, Sethi G. Targeting

cell signaling and apoptotic pathways by dietary agents: role in the prevention and treatment of cancer. Nutrition and Cancer. 2011;63(2):161-73. doi:https://doi.org/10.1080/01635581.2011.523502
26. Agarwal S, Sau S, Iyer AK, Dixit A, Kashaw SK. Multiple strategies for the treatment of invasive breast carcinoma: A comprehensive prospective. Drug Discovery Today. 2022;27(2):585-611. doi:https://doi.org/10.1016/j.drudis.2021.10.008
27. Wang X, Yang Y, An Y, Fang G. The mechanism of anticancer action and potential clinical use of kaempferol in the treatment of breast cancer. Biomedicine and Pharmacotherapy. 2019;117:109086. doi:https://doi.org/10.1016/j.biopha.2019.109086
28. Wang J, Fang X, Ge L, Cao F, Zhao L, Wang Z, et al. Antitumor, antioxidant and anti-inflammatory activities of kaempferol and its corresponding glycosides and the enzymatic preparation of kaempferol. PloS One. 2018;13(5):e0197563. doi:https://doi.org/10.1371/journal.pone.0197563
29. Alavi M, Karimi N. Biosynthesis of Ag and Cu NPs by secondary metabolites of usnic acid and thymol with biological macromolecules aggregation and antibacterial activities against multi drug resistant (MDR) bacteria. International Journal of Biological Macromolecules. 2019;128:893-901. doi:https://doi.org/10.1016/j.ijbiomac.2019.01.177
30. Tarbali S, Karimi N, Alavi M, Zahmatkesh M. Impact of green-synthesized silver nanoparticles on cognitive function and fluorescence spectroscopy of redox status in the hippocampus. Nanomedicine Research Journal. 2022;7(3):301-11. doi:https://doi.org/10.22034/nmrj.2022.03.010
31. Alyami NM, Alyami HM, Almeer R. Using green biosynthesized kaempferol-coated sliver nanoparticles to inhibit cancer cells growth: an in vitro study using hepatocellular carcinoma (HepG2). Cancer Nanotechnology. 2022;13(1):26. doi:https://doi.org/10.1186/s12645-022-00132-z
32. Alavi M, Yarani R. ROS and RNS modulation: the main antimicrobial, anticancer, antidiabetic, and antineurodegenerative mechanisms of metal or metal oxide nanoparticles. Nano Micro Biosystems. 2023;2(1):22-30. doi:https://doi.org/10.22034/nmbj.2023.382133.1012
33. Imran M, Salehi B, Sharifi-Rad J, Aslam Gondal T, Saeed F, Imran A, et al. Kaempferol: A Key Emphasis to Its Anticancer Potential. Molecules. 2019;24(12). doi:https://doi.org/10.3390/molecules24122277
34. Ming D, Wang D, Cao F, Xiang H, Mu D, Cao J, et al. Kaempferol Inhibits the Primary Attachment Phase of Biofilm Formation in Staphylococcus aureus. Frontiers in Microbiology. 2017;8. doi:https://doi.org/10.3389/fmicb.2017.02263
35. Adefegha SA, Salawi A, Bumrungpert A, Khorasani S, Torkaman S, Mozafari MR, et al. Encapsulation of polyphenolic compounds for health promotion and disease prevention: Challenges and opportunities. Nano Micro Biosystems. 2022;1(2):1-12. doi:https://doi.org/10.22034/nmbj.2023.163756
36. Amraei S, Ahmadi S. Recent studies on antimicrobial and anticancer activities of saponins: a mini-review. Nano Micro Biosystems. 2022;1(1):22-6. doi:https://doi.org/10.22034/nmbj.2022.160182
37. Alavi M, Nokhodchi A. Antimicrobial and wound healing activities of electrospun nanofibers based on functionalized carbohydrates and proteins. Cellulose. 2022;29(3):1331-47. doi:https://doi.org/10.1007/s10570-021-04412-6
38. Alavi M, Moetasam Zorab M, Ashengroph M, Aljelehawy QHA, Kahrizi D. Antibacterial and wound healing applications of curcumin in micro and nano-scaffolds based on chitosan, cellulose, and collagen: Antibacterial and wound healing applications of curcumin in micro and nano-scaffolds. Cellular and Molecular Biology. 2022;68(3):9-14. doi:https://doi.org/10.14715/cmb/2022.68.3.2
39. Ilk S, Sağlam N, Özgen M, Korkusuz F. Chitosan nanoparticles enhances the anti-quorum sensing activity of kaempferol. International Journal of Biological Macromolecules. 2017;94:653-62. doi:https://doi.org/10.1016/j.ijbiomac.2016.10.068
40. Mahdavi Dehkharghani F, Ghahremanlou M, Zandi Z, Jalili M, Mozafari MR, Mardani P. Future energy and therapeutic perspectives of green nano-technology: recent advances and challenges. Nano Micro Biosystems. 2023;2(1):11-21. doi:https://doi.org/10.22034/nmbj.2023.385185.1013
41. Alavi M, Hamblin MR, Kennedy JF. Antimicrobial applications of lichens: secondary metabolites and green synthesis of silver nanoparticles: A review. Nano Micro Biosystems. 2022;1(1):15-21. doi:https://doi.org/10.22034/nmbj.2022.159216
42. Kannanoor M, Lakshmi BA, Kim S. Synthesis of silver nanoparticles conjugated with kaempferol and hydrocortisone and an evaluation of their antibacterial effects. 3 Biotech. 2021;11(7):317. doi:https://doi.org/10.1007/s13205-021-02880-y

HOW TO CITE THIS ARTICLE:
Karimi N, Valizadeh M. Novel formulations of Kaempferol and its monosaccharide derivatives for healing cancers and microbial infections. Micro Nano Bio Aspects. 2023; 2(3): 7-12.
doi: https://doi.org/10.22034/mnba.2023.401346.1036