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PREFACE

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CHAPTER 1

A NEW SEARCH OF BIOACTIVE COMPOUNDS: ALGAE

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INTRODUCTION

The study of metabolic products of plants and other groups of organisms is not only for a better understanding of nature, but also includes the discovery of possible useful metabolites in different areas of interest to humans. In recent years, the discovery of some antiviral, antimicrobial, anticoagulant and growth-inhibiting metabolites, especially from macroalgae, has led to the emergence of a new industrial field.

Since algae have been used in traditional medicine for a long time, they have been intensively researched by various researchers (Evrim et al., 2010). Chemicals responsible for antibiotic activity are widely found in macroalgae. Of particular interest among these are haloforms, halogenated compounds such as halogenated alkanes and alkenes, alcohols, aldehydes, hydroquinones and ketones. There is also a long list of terpenoids with antibiotic properties, many of which are halogenated. Sterols, heterocyclic and phenolic compounds also sometimes show antibiotic properties.

However, for most of them, it can only show antimicrobial activity at concentrations where it is toxic (Evrim et al., 2010).

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detected. In the methanol extract, in addition to P-hydroxybenzoic acid, caffeic acid, p-coumaric acid, protocatechuic acid ethyl ester and vanillic acid, salicylic acid, ferulic acid metabolites, specifically caftaric acid and campferol were found. P-hydroxybenzoic acid, caffeic acid, p-coumaric acid, protocatechuic acid ethyl ester, protocatechuic acid and vanillic acid were found in the acetone extract of *Chara hispida*. The phenolic metabolites found in the DMSO extract of this algae were determined as gallic acid, gentisic acid, catechin, routine and cinnamic acid, as well as the phenolics in the acetone extract. It can also be emphasized that gallic acid and gentisic acid interact with other phenols in the *Chara hispida* DMSO/acetone extract mixture.

As we mentioned before, no other study was found regarding the antimicrobial activities of the algae extract mixtures included in the study and the antagonistic or synergistic interactions of these extracts. Therefore, the findings in our study can be claimed as the first records on the subject.

REFERENCES

Abd El-baky, H. H., El Baz, F. K., El-baroty, G. S. Characterization of nutraceutical compounds in blue green alga Spirulna maxima. Electronic Journal for Environmental, Agricultural and Food Chemistry, 8(11), 1113–1126, 2009.

Abedin, R. M. A., Taha, H. M. Antibacterial and antifungal activity of cyanobacteria and green microalgae. Evaluation of medium components by plackett-burman design for antimicrobial activity of Spirulina platensis. Global Journal of Biotechnology & Biochemistry, 3 (1): 22-31, 2008.

Adwan, G., Salameh, K., Adwan, K. Effect of extract Ecbalium elaterium against Staphyoccocus aureus and Candida albicans. Asian Pacific Journal of Tropical Biomedicine, 456-460, 2011.

Afifah, I. N., Darah, I. I., Fariza, I. S., Mohd Jain Nordin, M., K. Antimicrobial activity of various extracts of a tropical Chlorophyta macroalgae, Halimeda discoidea. Joumal of Applied Sciences, 10 (23): 3007 -30l3, 2010

Akyıl, D. Farklı Tipteki Fungusitlerin Muhtemel Mutajeniteleri Üzerine Bir Çahsma. Yüksek Lisans Tezi, Afyon Kocatepe Üniversitesti Fen Bilimleri Enstitüsü, Afyon, 1-21, 38-48, 2006.

Al- Haj N. A., Mashan N. I., Shamudin M. N., Antibacterial activity in marine algae Eucheuma denticulatum against Staphylococcus aureus and Streptococcus pyogenes. Research Journal of Biological Sciences, 4(4): 519-524, 2009.

Al-Amoudi, O. a., Mutawie, H. H., Patel, A. V., Blunden, G. Chemical composition and antioxidant activities of Jeddah corniche algae, Saudi Arabia. Saudi Journal of Biological Sciences, 16(1), 23–29, 2009.

Al-Saif, S. S. A., Abdel-Raouf, N., El-Wazanani, H. A., Aref, I. B. Antibacterial substances from marine algae isolated from Jeddah coast of Red sea, Saudi Arabia. Saudi Journal of Biological Sciences, 21: 57–64, 2014.

Ballantine, D. L., Gerwick, W. H., Velez, S. M., Alexander, E. and Guevara, P., Antibiotic activity of lipid-soluble extracts from Caribbean marine algae. Hydrobiologia, 151-152: 463–469, 1987.

Bansemir, A., Blume, M., Schröder, S., Lindequist, U., Screening of cultivated seaweeds for antibacterial activity against fish pathogenic bacteria. Aquaculture, 252: 79–84, 2006.

Bhagavathy, S., Sumathi, P., Jancy Sherene Bell, I. Green algae Chlorococcum humicola- a new source of bioactive compounds with antimicrobial activity. Asian Pacific Journal of Tropical Biomedicine, 1, S1–S7, 2011.

Bhateja, P., Mathur, T., Pandya, M., Fatma, T., Rattan, A. Activity of blue green microalgae extracts against in vitro generated Staphylococcus aureus with reduced susceptibility to vancomycin. Fitoterapia, 77(3), 233–235, 2006.

Borowitzka M. A., algal biotechnology products and processes–matching science and economics. Journal of Applied Phycology, 4: 267-279, 1992.
Boundless, "Primary and Secondary Metabolites." Boundless Microbiology. Boundless, https://www.boundless .com / microbiology / textbooks / boundless - microbiology - textbook /industrial - microbiology- 17/ industrial- microbiology – 198 /primary-and- secondary-metabolites-999-5345. (Temmuz, 2015).
Chinnu, K., Mukund, S., Muthukumaran, M., & Sivasubramanian, V. In vitro antioxidant activity of isolated beta glucan from Chroococcus turgidus. Journal of Algal Biomass Utilization, 6(3), 1–6, 2015.
Choudhury, S., Sree, A., Mukherjee, S. C., Pattnaik, P., ve Bapuji, M., in vitro antibacterial activity of extracts of selected marine algae and mangroves against fish pathogens. Asian Fisheries Science, 18: 285-294, 2005.
Cowan, M. M., Plant products as antimicrobial agents. Clinical Microbiology Reviews, 12(4): 564-581, 1999.
Danyal, A., Mubeen, U., Malik, K. A., Investigating two native algal species to determine antibiotic susceptibility against some pathogens. Current Research Journal of Biological Sciences, 5: 70-74, 2013.
Debnath, A. K., Compadre, R. L., Debnath, G., Shusterman, A. J., and Hansch, G. Structure-activity relationship of mutagenic aromatic and heteroaromatic nitro compounds correlation with molecular orbital energies and hydrophobicity. Journal of Medicinal Chemistry, 34(2), 786-797, 1991.
Deshmukh D. V., Puranik P. R. Application of Plackett-Burman Design to evaluate media components affecting antibacterial activity of alkaliphilic cyanobacteria isolated from Lonar Lake. Türk Biyokimya Dergisi. (Turkish Journal of Biochemistry), 35 (2): 114–120, 2010.
Dhanalakshmi M., Angayarkanni, J. Phytochemistry and antibacterial activity of chlorosarcinopsis species. International journal of scientific & technology research, 2: 10, 315-321, 2013.
Ely, R., Supriya, T., Naik, C. G., Antimicrobial activity of marine organisms collected off the coast of South East India. Journal of Experimental Marine Biology and Ecology, 309:121 – 127, 2004.
Eom, S., Park, J., Yu, D., Choi, J., Choi, J., Lee, M., & Kim, Y., antimicrobial activity of brown alga eisenia bicyclis against methicillin-resistant Staphylococcus aureus. Fisheries and Aquatic Sciences, 251–256, 2011.
Evrim, T., Çakı, Z., Öztürk, M., Taşkın, M., Kurt, O., Antimicrobial and antitumoural activities of marine algae. Review of Hydrobiology, 3(1): 37-50, 2010.
Felício, R., Albuquerque, S., Marx Young, M. C., Yokoya, N. S., Debonsi, H. M. Trypanocidal, leishmanicidal and antifungal potential from marine red alga Bostrychia tenella J. Agardh (Rhodomelaceae, Ceramiales). Journal of Pharmaceutical and Biomedical Analysis, 52: 763–769, 2010.
Goiris, K., Muylaert, K., Fraeye, I., Foubert, I., De Brabanter, J., & De Cooman, L. Antioxidant potential of microalgae in relation to their phenolic and carotenoid content. Journal of Applied Phycology, 24(6), 1477–1486, 2012.
Goiris, K., Muylaert, K., Fraeye, I., Foubert, I., De Brabanter, J., & De Cooman, L. Antioxidant potential of microalgae in relation to their phenolic and carotenoid content. Journal of Applied Phycology, 24(6), 1477–1486, 2012.
Gökpınar Ş., Koray T., Akçiçek E., Göksan T., Durmaz Y., (2006). Algal Antioksidanlar. E.U. Journal of Fisheries & Aquatic Sciences, 23: 85-89, 2006.
Guiry, M., Seaweed uses and utilization. http://www.seaweed.ie/uses_general/ humanfood.lasso, 2008.
Hajimahmoodi, M., Faramarzi, M. A., Mohammadi, N., Soltani, N., Oveisi, M. R., Nafissi-Varcheh, N. Evaluation of antioxidant properties and total phenolic contents of some strains of microalgae. Journal of Applied Phycology, 22(1), 43–50, 2009.
Hemalatha, A, Girija, K., Parthiban, C., Saranya, C., & Anantharaman, P. (2013). Antioxidant properties and total phenolic content of a marine diatom , Navicula clavata and green microalgae , Chlorella marina and Dunaliella salina, Pelagia Research Library, 4(5), 151–157, 2013.
Hilmi Ş., Oksidanlar ve antioksidanlar. THTD. 48:1-2, 44-49, 1994.
Ibañez, E., Herrero, M., Mendiola, J. a, & Castro-puyana, M. Marine bioactive compounds. Extraction and characterizaton of bioactive compounds with health benefits, Marine Bioactive Compounds, 2012.
Julkunen-Tiitto R. Phenolic Constituents in the Leaves of Northern Willows: Methods for the Analysis of Certain Phenolics. Journal of Agricultural Food Chemistry. 33(2) 213-217, 1985.
Kandhasamy M, Arunachalam K. D., Evaluation of in vitro antibacterial property of seaweeds of southeast coast of India. African Journal of Biotechnology, 7(12): 1958-1961, 2008.
Karagozler A. A., Erdag B., Calmaz Emek Y., Aktas Uygun D. Antioxidant activity and proline content of leaf extracts from Dorystoechas hastata. Food Chemistry, 111: 400–407, 2008.

Kartal, M., Orhan, I., Abu-Asaker, M.,Senol, F., S., Atıcı, T., Sener, B., antioxidant and anticholinesterase assets and liquid chromatography-mass spectrometry preface of various fresh-water and marine macroalgae. Pharmacognosy Magazine. 5(20): 291- 297, 2009.

Katırcıoğlu H., Beyatli Y., Aslim B., Yüksekdag Z., Atici T. Screening of antimicrobial agent production of some microalgae in freshwater. The internet journal of Microbiology, 2006. c. Antibacterial Activity from Marine Microalgae in Laboratory Culture. Journal of Phycology,24:191-194, 1989.

Khoddami, A., Wilkes, M. a., Roberts, T. H. Techniques for analysis of plant phenolic compounds. Molecules, 18(2), 2328–2375, 2013

Kitada, K., Goto, M., Machmudah, S., Nakashima, Y., Hasegawa, T., Sasaki, M. ve Kumamoto, S. Antioxidant and antibacterial activity of nutraceutical compounds from Chlorella vulgaris extracted in hydrothermal condition. Separation Science and Technology, 44: 1228–1239, 2009.

Kosanic, M., Rankovic, B., Stanojkovic, T. Biological activities of two macroalgae from Adriatic coast of Montenegro. Saudi Journal of Biological Sciences, 22: 390–397, 2015.

Kuda, T., Tsunekawa, M., Goto, H., Araki, Y. Antioxidant properties of four edible algae harvested in the Noto Peninsula, Japan. Journal of Food Composition and Analysis, (18): 625–633, 2005.

Kutlu, M., Öztaş, E., Aydoğan, G., Işıkdağ, İ., Özkay, Y. Bazı 9-Sübstitüe fenantren türevlerinin mutajenik aktivitelerinin/ salmonella / mikrozom testi ile araştirilmasi. Anadolu university journal of science and technology –C. Life Sciences And Biotechnology Cilt/Vol.:1-Sayı/No: 1: 83-94, 2011.

Li, Y., Z.J. Qian, B.M. Ryu, S.H. Lee, M.M. Kim, and S.K. Kim. Chemical components and its antioxidant properties in vitro: an edible marine brown alga, Ecklonia cava . Bioorganic & Medicinal Chemistry, 17: 1963–1973, 2009.

López A., Rico M., Rivero A., Suárez de Tangil M. The effects of solvents on the phenolic contents and antioxidant activity of Stypocaulon scoparium algae extracts. Food Chemistry, 125: 1104–1109, 2011.

Manivannan, K., Karthikai devi, G., Anantharaman, P., Balasubramanian, T. Antimicrobial potential of selected brown seaweeds from Vedalai coastal waters, Gulf of Mannar. Asian Pacific Journal of Tropical Biomedicine 114-120, 2011.

Maron, D. R. and Ames, B. N. Revised Methods for the Salmonella Mutagenicity Test. Mutation Research, 113: 173-215, 1983.

Megharaj, M., Venkateswarlu, K., Rao, A.S., The use of unicellular soil green algae for insecticide bioassay. Journal of Microbiolojical Methods. 10(2): 119-122, 1989.

Merkl, R., Hrádková, I., Filip, V., & Šmidrkal, J. Antimicrobial and antioxidant properties of phenolic acids alkyl esters. Czech Journal of Food Science, 28(4), 275–279, 2010.

Mohsin S., Mahadevan R., Muraleedhara Kurup G. Free-radical-scavenging activity and antioxidant effect of ascophyllanfrom marine brown algae Padina tetrastromatica. Biomedicine & Preventive Nutrition, 4(1): 75-79, 2013.

Mtolera, M. S. P. and Semesi, A. K., Antimicrobial activity of extraxts from six green algae from Tanzania. In: Cur. Trends Mar. Botanical Research, 211–217, 1996.

Najdenski H. M., Gigova L. G., Iliev I. I., Pilarski P. S., Lukavsky J., Antibacterial and antifungal activities of selected microalgae and cyanobacteria. International Journal of Food Science and Technology, 48: 1533-1540, 2013.

Oh, K. B., Lee, J. H., Chung, S. C., Kim, H. K., Shin, J., Lee, H. S., Shin, H. J., Antimicrobial activities of the bromophenols from the red alga Odonthalia corymbifera and some synthetic derivatives. Bioorganic & Medicinal Chemistry, Letters 18:104–108, 2008.

Ozcan, T., Akpinar-Bayizit, a., Yilmaz-Ersan, L., & Delikanli, B. Phenolics in Human Health. International Journal of Chemical Engineering and Applications, 5(5), 393–396, 2014.

Ozdemir G., Horzum Z., Sukatar A., Karabay-Yavasoglu U., Antimicrobial activities of volatile components and various extracts of dictyopteris membranaceae and cystoseira barbata from the Coast of Izmir, Turkey. Pharmaceutical Biology, 44(3): 183–188, 2006.

Pai, C. A. Foundation of Genetics, A Science for Society. Keyford Press, Singapur, 28- 33, 1985.

Patra, J.K., Patra, A. P., Mahapatra, N. K., Thatoi, H. N., Das, S., Sahu, R. K. and Swain, G. C., Antimicrobia activity of organic solvent extracts of three marine macroalgae from Chilika Lake, Orissa, India. Malasian Journal of Microbiology.5: 128-131, 2009.

Prakash J. W., Antonisamy J. M., Solomon J. Antimicrobial activity of certain fresh water microalgae from Thamirabarani River, Tamil Nadu, South India. Asian Pacific Journal of Tropical Biomedicine, S170-S173, 2011.

Priyadharshini, S., Bragadeeswaran, S., Prabhu, K., & Ran, S. S. Antimicrobial and hemolytic activity of seaweed extracts Ulva fasciata (Delile 1813) from Mandapam, Southeast coast of India. Asian Pacific Journal of Tropical Biomedicine, 1(1), S38– S39, 2011.

Rainer-B. Volk, Franz H. Furkert, Antialgal, antibacterial and antifungal activity of two metabolites produced and excreted by cyanobacteria during growth. Microbiological Research, 161: 180—186, 2006.

Rippka, R., Detruelles J., Waterbury J.B., Herdman, L., Stainer R., (1979). Generic assignments, strain histories and properties of pure cultures of cyanobacteria. Journal of Genetics Microbiology, 111: 1-61, 1979.

Rosaline, X. D., Sakthivelkumar, S., Rajendran, K., Janarthanan, S. Screening of selected marine algae from the coastal Tamil Nadu, South India for antibacterial activity. Asian Pacific Journal of Tropical Biomedicine, S140-S146, 2012.

Salem, W. M., Galal, H. and Nasr El-deen, F. Screening for antibacterial activities in some marinealgae from the red sea (Hurghada, Egypt). African Journal of Microbiology Research, 5(15): 2160-2167, 2011.

Santoyo, S., Rodri, I., Meizoso, G., Cifuentes, A., Jaime, L., Garcia, G., Reina, B., Ibanez, I. Green processes based on the extraction with pressurized fluids to obtain potent antimicrobials from Haematococcus pluvialis microalgae. LWT - Food Science and Technology 42: 1213–1218, 2009.

Sasidharan, S., Darah, I., Noordin, M. K. M. J. Ivitro antimicrobial activity against Pseudomonas aeruginosa and acute oral toxicity of marine algae Gracilaria changii. New Biotechnology. 27 (4): 390-396, 2010.

Shamchi, M., Investigation of bioactive compounds of cyanobacteria and some algal species, Hacettepe University, 2016

Smit, A.J., Medicinal and pharmaceutical uses of seaweed natural products: A review. Journal of Applied Phycology, 16: 245–262, 2004.

Solomon R.D.J and Santhi V.S., Purification of bioactive natural product against human microbial pathogens from marine seaweed Dictyota acutiloba. J. Ag. World Journal of Microbiological Biotechnology, 24: 1747- 1752, 2008.

Stojković D., Petrović J., Soković M., Glamočlija J., Kukić-Marković J., Petrović S.(2013). In situ antioxidant and antimicrobial activities of naturally occurring caffeic acid, p-coumaric acid and rutin, using food systems. Journal of Science Food and Agriculture, 93(13):3205-8, 2013.

Suganthy, N., Arif Nisha, S., Pandian, S. K., Devi, K. P. Evaluation of Gelidiella acerosa, the red algae inhabiting South Indian coastal area for antioxidant and metal chelating potential. Journal of Chemistry,5. 472-478, 2013.

Suhail, S., Biswas, D., Farooqui, A., Arif, J. M., Zeeshan, M. Antibacterial and free radical scavenging potential of some cyanobacterial strains and their growth characteristics. Journal of Chemistry, 3(2):472-478, 2011.

Susilowati, R., Sabdono, A., Widowati, I. Isolation and Characterization of Bacteria Associated with Brown Algae Sargassum spp. from Panjang Island and Their Antibacterial Activities. Procedia Environmental Sciencese, 23: 240 – 246, 2015.

Temizkan, G. Molekuler Genetik. İstanbul Üniversitesi Yayınları, İstanbul, 35-39, 1996.

Tüney, İ., Adirci, B. H., Ünal, D., Sukatar, A. Antimicrobial Activities of the Extracts of Marine Algae from the Coast of Urla (Üzmir, Turkey). Turkish Journal of Biology. 30: 171-175, 2006.

Uma, R., Sivasubramanian, V. ve Devaraj, S. N. Preliminary phycochemical analysis and in vitro antibacterial screening of green micro algae, Desmococcus Olivaceous, Chlorococcum humicola and Chlorella vulgaris. Journal of Algal Biomass, 2 (3): 74– 81, 2011.

Wei Y.H., C.Y. Pang, The Role of Mitocondria in human aging process. Biotech International, 17: 8-13. Wiese, M., D'Agostino, P.M., Mihali, T. K., Moffitt, M. C. and Neilan, B. A., Neurotoxic Alkaloids: Saxitoxin and Its Analogs, Marine Drugs, 8: 2185- 2211,2010.

Yazdani, D., Tan Y. H., Zainal Abidin M., and Jaganath I. A review on bioactive compounds isolated from plants against plant pathogenic fungi. Journal of Medicinal Plants Research, 5(30), 6584–6589, 2011.

Yong Song, M., Kwang Ku, S., Soo Han, J. Genotoxicity testing of low molecular weight fucoidan from brown seaweeds. Food and Chemical Toxicology, 50: 790–796, 2012.

Zubia, M., Robledo, D., Freile-Pelegrin, Y. Antioxidant activities in tropical marine macroalgae from the Yucatan Peninsula, Mexico. Journal of Applied Phycology, 19:449– 458, 2007.

CHAPTER 2

THE MEDICINAL-AROMATIC PROPERTIES of GINGER *(Zingiber officinale)* PLANT and TISSUE CULTURE STUDIES

Çiğdem Alev ÖZEL[1]
Yiğit Buğra AKYÖN[2]

INTRODUCTION

Throughout history, human beings have used plants for nutrition, shelter, warmth, sheltering their wounds and treating their diseases (Acıbuca and Budak, 2018). The first records of plant-based treatment date back to around 5000 BCE in the Mesopotamian civilization, where the use of 250 herbal drugs for therapeutic purposes has been identified (Demirezer, 2010). The aromatic use of plants and the extraction of essential oils can be traced back to ancient times, with a notable example found in the Ebers Papyrus, dating back to the 16th century BCE, discovered by the German Egyptologist Georg Ebers in 1872. The concept of aromatic medicine is evident in the papyrus, where it is discussed as a concept, and various treatment methods are described (Carpenter et. al., 2006). Over time, with advancements in technology, the addition of synthetic substances to food and beverages, as well as the introduction of synthetic drugs into production, has led to a decline in the traditional use of medicinal and aromatic plants. In the twentieth century, the discovery of side effects associated with synthetic drugs and the awareness of the harm caused by synthetic substances in food and beverages to human health have come to light. The increasing demand for traditional medicinal and aromatic plants has led to a return to natural products, with people shifting their focus towards natural and herbal products, primarily for health reasons. As a result, there has been a renewed interest in traditional medical practices, and herbal treatments have started to gain greater acceptance in the field of alternative

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REFERENCES

Acıbuca, V., & Budak, D. B. (2018). Dünya'da ve Türkiye'de tıbbi ve aromatik bitkilerin yeri ve önemi. *Çukurova Tarım ve Gıda Bilimleri Dergisi*, *33*(1), 37-44.

Ahmad, I., Zahin, M., Aqil, F., Hasan, S., Khan, M. S. A., & Owais, M. (2008). Bioactive compounds from *Punica granatum*, *Curcuma longa* and *Zingiber officinale* and their therapeutic potential. *Drugs of the Future. 33*(4), 329-346.

Ahmed, K., Shaheen, G., & Asif, H. M. (2011). Zingiber officinale Roscoe (pharmacological activity). *Journal of Medicinal Plants Research*, *5*(3), 344-348.

Ali, B.H., et al. (2008). Some phytochemical, pharmacological and toxicological properties of ginger (*Zingiber officinale* Roscoe): A review of recent research. *Food Chem Toxicol, 46*. 409-20.

Al-Taha, H. A., Al-Mayah, A. A., & Abd Al-Behadili, W. A. (2020). Efficient in vitro regeneration of *Zingiber officinale* Rosc. var. White through shoot tips culture. *Plant Archives*, *20*(1), 434-437.

Anandaraj, M., S. Devasahayam, T. J. Zachariah, S. J. Eapen, B. Sasikumar & C. K. Thankamani. (2001). Ginger. *(extension pamphlet)* Agricultural Technology Information Centre. *Indian Institute of Spices Research,* Calicut, Kerala.

Antonietta, G. M., Ahmad, H. I., Maurizio, M. Alvaro, S. (2007). Preliminary research on conversion of encapsulated somatic embryos of *Citrus reticulata* Blanco, cv. Mandarino Tardivo di Ciaculli. *Plant Cell Tissue and Organ Culture, 88*(1):117-120.

Ayenew, B., Tefera, W., & Kassahun, B. (2012). In vitro propagation of Ethiopian ginger (Zingiber officinale Rosc.) cultivars: Evaluation of explant types and hormone combinations. *African Journal of Biotechnology*, *11*(16), 3911-3918.

Babu, K. N., Samsudeen, K., & Ratnambal, M. J. (1992). *In vitro* plant regeneration from leaf-derived callus in ginger (*Zingiber officinale* Rosc.). *Plant Cell, Tissue and Organ Culture*, *29*, 71-74.

Baliga, M. S., Haniadka, R., Pereira, M. M., D'Souza, J. J., Pallaty, P. L., Bhat, H. P., & Popuri, S. (2011). Update on the chemopreventive effects of ginger and its phytochemicals. *Critical Reviews in Food Science and Nutrition*, *51*(6), 499-523.

Basile, A., & Rigano, D. (2017). Plants of the genus Zingiber as a source of bioactive phytochemicals: From tradition to pharmacy. *Molecules, 22*(12), 1-20.

Bayar, F. U. (2020). Doğadan gelen mucize: Zencefil (*Zingiber officinale*). *Bahçe, 49*(2), 99-110.

Bayraktar, D. Z. (2021). Zencefil'in (*Zingiber officinale* Roscoe) insan sağlığı üzerine çeşitli terapötik etkileri. *Karya Journal of Health Science*, *2*(2), 55-60.

Bertila, S., Ariina, M. S., Maiti, C. S., Gadi, Y., & Daiho, L. (2020). Effect of planting time and harvest on yield and quality of ginger (*Zingiber officinale* Rosc.) cv. Nadia. *International Journal of Chemical Studies*, *8*(5), 1922-1925.

Bhattacharya, M., & Sen, A. (2006). Rapid in vitro multiplication of disease-free *Zingiber officinale* Rosc. *Indian Journal of Plant Physiology*, *11*(4), 379.

Bilgin Göçmen, G., Arslantunalı Tağtekin, D., Yanıkoğlu, F. (2020). Bitkisel diş macunları. Arslantunalı Tağtekin D, editör. *Diş Macun ve Kremleri*. *Türkiye Klinikleri. 1*.97-106.

Black, C. D., Herring, M. P., Hurley, D. J., & O'Connor, P. J. (2010). Ginger (*Zingiber officinale*) reduces muscle pain caused by eccentric exercise. *The Journal of Pain*, *11*(9), 894-903.

Buckle, J. (2003). *Clinical Aromatherapy.* 2nd Edition, New York: Churchill Livingstone.

Bürün, B. (2001). Bitki Biyoteknolojisi I Doku Kültür ve Uygulamaları, *Hastalıksız Bitki Üretimi*, (Eds. Sebahattin Özcan, Ekrem Gürel ve Mehmet Babaoğlu), Konya: S.Ü. Vakfı Yayınları, s.211-261.

Carpenter, S., Rigaud, M., Barile, M., Priest, T. J., Perez, L., & Ferguson, J. B. (2006). The Ebers Papyrus. *Bard College*, *3*.

CITES (2023) The Convention on International Trade In Endangered Species of Wild Fauna and Flora. Accessed on 2.11.2023, https://cites.org/eng/prog/medplants from the address.

David, D., Ji, T. Y., & Gansau, J. A. (2016). In Vitro Propagation of Zingiber officinale Rosc.'Tambunan'. *Transactions on Science and Technology*, *3*(1-2), 162-167.

Demirçivi, B. M., & Altaş, A. (2016). Üniversite Öğrencilerinin Baharatlara İlişkin Bilgileri ve Tüketim Tercihleri: Aksaray Üniversitesinde Bir Uygulama*, Journal of Tourism and Gastronomy Studies, 4*(4), 88-112.

Demirezer, L.Ö. (2010). *Bitkilerin tıpta kullanılması konusundaki sorumluluklarımız*. Bitkilerle Tedavi Sempozyumu 5-6 Haziran 2010 Zeytinburnu/İstanbul Bildiri Kitabı, s: 87- 88.

Elbir, Z. G. (2000). *Gayetü'l-Beyan Fi Tedbiri Bedeni'l-İnsan*. Yayınlanmamış Doktora Tezi, Fırat Üniversitesi, Sosyal Bilimler Enstitüsü, Elâzığ.

El-Nabarawy, M. A., El-Kafafi, S. H., Hamza, M. A., & Omar, M. A. (2015). The effect of some factors on stimulating the growth and production of active substances in Zingiber officinale callus cultures. *Annals of Agricultural Sciences*, *60*(1), 1-9.

Gezahegn, G., Feyissa, T., & Rezene, Y. (2023). Replacement of ammonium nitrate by alternative nitrogen sources in MS medium to enhance ginger (Zingiber officinale Rosc.) *in vitro* regeneration. *Plant Cell, Tissue and Organ Culture*, 1-7.

Ghosh, A.K., (2011). *Zingiber officinale*: a natural gold. *International Journal of Pharma and Bio Sciences*, *2*(1).

Göktaş, Ö., & Gıdık, B. (2019). Tıbbi ve aromatik bitkilerin kullanım alanları. *Bayburt Üniversitesi Fen Bilimleri Dergisi*, *2*(1), 145-151.

Guo, Y., & Zhang, Z. (2005). Establishment and plant regeneration of somatic embryogenic cell suspension cultures of the *Zingiber officinale* Rosc. *Scientia Horticulturae*, *107*(1), 90-96.

Hartmann, H. T., & Kester, D. E. (2002). *Plant propagation: principles and practices*. 7th Edition, USA Pearson Education.

Higgins, S., Rose, K., Wilson, R., Francis, R. D., Watson, C. T., & Riley, C. K. (2020). In Vitro Propagation of *Zingiber Officinale* Rosc. *Biotechnological Research*, *6*(1), 1-6

İzer, M. (1988). *Baharatın İzleri*. İstanbul: Sev Matbaacılık ve Yayıncılık A.Ş.

Jenkins, M., Timoshyna, A., Cornthwaite, M. (2018) Wild at home. Exploring the global harvest, trade and use of wild plant ingredients. TRAFFIC, Cambridge, UK. https://www.traffic.org/site/assets/files/7339/wild-at-home.pdf Accessed on 2.11.2023, from the address.

Jo, M. H., Ham, I. K., Lee, M., Park, S. K., Kwon, K. H., & Lee, E. M. (2009). Efficient production of ginger (*Zingiber officinale* Roscoe) rhizome by shoot-tip culture. *Korean Journal of Plant Resources*, *22*(6), 518-521.

Jolad, S. D., Lantz, R. C., Solyom, A. M., Chen, G. J., Bates, R. B., & Timmermann, B. N. (2004). Fresh organically grown ginger (*Zingiber officinale*): composition and effects on LPS-induced PGE2 production. *Phytochemistry, 65*(13), 1937-1954.

Kadambari, S., & Bhawna, M. (2014). Invitro Conservation of *Zingiber officinale* through rhizome. *IOSR Journal of Pharmacy and Biological Sciences, 9*(3), 39-40

Kaplan, H. (2014). Zencefilin (*zingiber officinale* roscoe) bitkisel özellikleri ve yetiştiriciliği. *Derim*. *22*(2):1-9.

Kar, Z., Yazar, K., Doğan, O., & Yazıcı, S. (2023). Sentetik Tohum ve Bağcılıkta Kullanımı. *Bahçe, 52*(Özel Sayı 1), 418-433.

Kemper, K. J. (1999). Ginger (Zingiber officinale). *Longwood Herbal Task Force*, *3*, 1-18.

Khandouzi, N., Shidfar, F., Rajab, A., Rahideh, T., Hosseini, P., Taheri, M.M. (2015). The effects of ginger on fasting blood sugar, hemoglobin Alc, and lipid profiles in patients with type 2 diabetes. *Iranian Journal of Pharmaceutical Research*. *14*(1):131-140.

Khayat, S., Kheirkhah, M., Behboodi Moghadam, Z., Fanaei, H., Kasaeian, A., & Javadimehr, M. (2014). Effect of treatment with ginger on the severity of premenstrual syndrome symptoms. *International scholarly research notices*. *2014*.

Kılıç, A. (2008). Uçucu yağ elde etme yöntemleri. *Bartın Orman Fakültesi Dergisi, 10*(13), 37-45.4

Kumar, G., Karthik, L., Rao, KVB. (2011). A review on pharmacological and phytochemical properties of *Zingiber officinale* Roscoe (Zingiberaceae). *Journal of Research in Pharmacy, 4*(9), 2963-2966.

Kumar, K. M. P., Asish, G. R., and Balachandran, I. (2013). Significance of gingers (Zingiberaceae) in Indian system of medicine- Ayurveda: An overview. *Ancient Science of Life, 4*(32), 253-261.

Li, Y., Tran, VH., Duke, CC., Roufogalis, BD. (2012). Preventive and protective properties of *Zingiber officinale* (ginger) in diabetes mellitus, diabetic complications, and associated lipid and other metabolic disorders: a brief review. *Evidence-Based Complementary and Alternative Medicine* https://doi.org/10.1155/2012/516870

Liju, VB., Jeena, K., Kuttan, R. (2015). Gastroprotective activity of essential oils from turmeric and ginger. *Journal of Basic and Clinical Physiology and Pharmacology*. *26*(1), 95-103. doi: 10.1515/jbcpp-2013-0165.

Lincy, A. K., Remashree, A. B., & Sasikumar, B. (2004). Direct multiple shoot induction from aerial stem of ginger (*Zingiber officinale* Rosc.). *Journal of Applied Horticulture*, *6*(2), 99-101.

Mansuroğu, S., & Gürel E. (2001). Bitki Biyoteknolojisi I Doku Külütür ve Uygulamaları, *Mikroçoğaltım*, (Eds. Sebahattin Özcan, Ekrem Gürel ve Mehmet Babaoğlu), Konya: S.Ü. Vakfı Yayınları, s.262-281.

Meenu, G., & Kaushal, M. (2017). Diseases infecting ginger (Zingiber officinale Roscoe): A review. *Agricultural Reviews*, *38*(1), 15-28.

Mohd Yusof, Y. A. (2016). Gingerol and its role in chronic diseases. *Drug Discovery from Mother Nature*, *929*. 177-207. https://doi.org/10.1007/978-3-319-41342-6_8

Mol, J., Salim, V., Chemparathy, S. M., Karim, R., & Umesh, B. T. (2016). An efficient protocol for raising contamination free micropropagation of *Zingiber officinale* (Ginger). *Journal of Pharmaceutical and Biological Sciences*, *4*(5), 145.

Nahin, R.L. (2007). *Costs of Complementary and Alternative Medicine (CAM) and Frequency of Visits to CAM Practitioners: United States*: Diane Publishing.

Nair, K. P. (2013). *The agronomy and economy of turmeric and ginger: the invaluable medicinal spice crops*. Newnes.

National Center for Health Statistics (US). (2008). *National health statistics reports* (No. 13-31). US: Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Health Statistics.

Onay, A., Yıldırım, H., Pirinç, V., et al. (2012). Bitkilerin Biyoteknolojik Yöntemlerle Ticari Çoğaltımı; Mevcut Durum ve Gelecekteki Durum. *Batman Üniversitesi Journal of Life Sciences,1*(2), 11-27.

Özcan, S., Babaoğlu, M., & Sancak, C. (2001). Bitki Biyoteknolojisi I Doku Kültürü ve Uygulamaları, Doku Kültürü: *Temel Laboratuvar Teknikleri,* (Eds. Sebahattin Özcan, Ekrem Gürel ve Mehmet Babaoğlu), Konya: S.Ü. Vakfı Yayınları, s.71-88.

Park, E. J., Pezzuto, J. M. (2002). Botanicals in cancer chemoprevention. *Cancer and Metastasis Reviews*, *21*(3-4), 231-255.

PDR For Herbal Medicines. (2000). Montwale-New Jersey: Medical Economics Company.

Rout, G. R., Palai, S. K., Samantaray, S., & Das, P. (2001). Effect of growth regulator and culture conditions on shoot multiplication and rhizome formation in ginger (*Zingiber officinale* Rosc.) in vitro. *In Vitro Cellular & Developmental Biology-Plant, 37*, 814-819.

Ryan, J.L., Heckler, C.E., Roscoe, J.A., et al. (2012). Ginger (zingiber officinale) reduces acute chemotherapy-induced nausea: a URCC CCOP study of 576 patients. *Support Care in Cancer. 20*(7):1479-1489

Sainani, G. S., Desai, D. B., Gorhe, N. H., Natu, S. M., Pise, D. V., Sainani, G. B. (1979). Effect of dietary garlic and onion on serum lipid profile in Jain community. *Indian Journal of Medical Research. 69*, 776-780.

Sathyagowri, S., & Seran, T. H. (2011). In vitro plant regeneration of ginger (*Zingiber officinale Rosc.*) with emphasis on initial culture establishment. *International Journal of Medicinal and Aromatic Plants*, *1*(3), 195-202..

Shaik, J. (2018). In vitro propagation of Zingiber officinale through rhizome and effect of plant growth regulators. *Journal of Pharmacognosy and Phytochemistry*, *7*(5), 2012-2014.

Sharifi-Rad, M., Varoni, E. M., Salehi, B., Sharifi-Rad, J., Matthews, K. R., Ayatollahi, S. A., et al. (2017). Plants of the genus *Zingiber* as a source of bioactive phytochemicals: From tradition to pharmacy. *Molecules*, *22*(12), 2145.

Sharma, T. R., Singh, B. M., & Chauhan, R. S. (1994). Production of disease-free encapsulated buds of *Zingiber officinale* Rosc. *Plant Cell Reports*, *13*(5), 300-302.

Solanki, R. U., Parekh, M. J., & Patel, S. R. (2014). Regeneratıon of Gınger (*Zingiber officinale rosc.*) Through shoot tıp culture. *Journal of Cell and Tissue Research*, *14*(2), 4409.

Sökmen, A., & Gürel E. (2001). Bitki Biyoteknolojisi I Doku Kültür ve Uygulamaları, *Sekonder Matabolit Üretimi*, (Eds. Sebahattin Özcan, Ekrem Gürel ve Mehmet Babaoğlu), Konya: S.Ü. Vakfı Yayınları, s.190-210.

Stea, S., Beraudi, A., & De Pasquale, D. (2014). Essential oils for complementary treatment of surgical patients: state of the art. *Evidence-Based Complementary and Alternative Medicine*, *2014*.

Sugiyama, M. (1999). Organogenesis *in vitro*. *Current Opinion in Plant Biology*, *2*(1), 61-64

Sukarnih, T., Rudiyana, Y., Hanifah, N. F., & Sa'adah, N. (2021). Micropropagation of red ginger (*Zingiber officinale* Rosc. Var. rubrum) using several types of cytokinins. In *Journal of Physics: Conference Series, 1751*(1), doi:10.1088/1742-6596/1751/1/012051

Süzgeç-Selçuk, S., & Eyisan, S. (2012). Türkiye'deki eczanelerde bulunan bitkisel ilaçlar. *Marmara Pharmaceutical Journal*, *16*(3), 164-180.

Şeker, M. (2011). *Bitkilerdeki Şifa*. Bursa: Ekin Basım Yayın Dağıtım.

Şentürk, S., & Taşcı, S. (2019). Osteoartritte ağrı ve zencefilli böbrek kompres uygulaması. *Arşiv Kaynak Tarama Dergisi, 28*(3), 201-210.

Tez, Z. (2012). *Lezzetin tarihi: Geçmişten bugüne yiyecek, içecek ve keyif vericiler.* İstanbul: Hayykitap.

Tyagi, R. K., Agrawal, A., & Yusuf, A. (2006). Conservation of Zingiber germplasm through *in vitro* rhizome formation. *Scientia Horticulturae*, *108*(2), 210-219.

Ungvarsky, J. (2017). *Ginger (Zingiber officinale).* Salem Press Encyclopedia.Ali, A. M. A., El-Nour, M. E. M., & Yagi, S. M. (2016). Callus induction, direct and indirect organogenesis of ginger (Zingiber officinale Rosc). *African Journal of Biotechnology*, *15*(38), 2106-2114.

Villamor, C. C. (2010). Influence of media strength and sources of nitrogen on micropropagation of ginger, *Zingiber officinale* Rosc. *E-International Scientific Research Journal*, *2*(2), 150-155.

World Health Organization. (2000). *WHO monographs on selected medicinal plants* (Vol. 2). World Health Organization.

Yalçın, A. (2000). *Baharat Grupları*. İstanbul: Geçit Kitabevi.

Yamuna, G., Sumathi, V., Geetha, S. P., Praveen, K., Swapna, N., & Nirmal Babu, K. (2007). Cryopreservation of in vitro grown shoots of ginger (*Zingiber officinale* Rosc.). *CryoLetters*, *28*(4), 241-252.

Zuraida, A. R., Mohd, S. M. A., Erny, S. M. N., Ayu, N. O., Che, R. C. Z., Pavallekoodi, G., & Sreeramanan, S. (2016). Micropropagation of ginger (*Zingiber officinale var. Rubrum*) using buds from microshoots. *Pakistan Journal of Botany*, *48*(3), 1153-1158.

CHAPTER 3

THE MEDICINAL-AROMATIC PROPERTIES of TURMERIC (*Curcuma longa*) PLANT and TISSUE CULTURE STUDIES

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INTRODUCTION

Throughout history, it is unimaginable to think of a time when humans and plants were separate entities. Starting with the history of humanity, plants have been utilized for various purposes such as food, clothing, fuel, and shelter. In the subsequent periods, humans have discovered additional properties of plants, incorporating the therapeutic benefits of specific plants into their lives (Jamshidi-Kia, Lorigooini, and Amini-Khoei, 2017). A Sumerian clay tablet dating back approximately 5000 years is considered one of the oldest written evidences indicating the use of medicinal plants for preparing remedies. Discovered in Nagpur, this tablet references over 250 different plants, including poppy, henbane, and mandrake, all containing alkaloids. It provides detailed instructions for preparing medicines from these plants, marking a significant historical record of early pharmacological knowledge (Castiglioni, 2019). In the ancient Chinese medical text "Pen T'Sao," believed to have been written around 2500 B.C., information is provided about the use of plants, including drugs that are still in use today, along with their respective applications (Wiart, 2007). In the wisdom of ancient Indian culture, as documented in the Vedic teachings and sacred texts, there is a detailed account of plants used in Ayurvedic medicine. The extracts of these plants are intricately described, often associated with deities in their belief system. Many plants, such as turmeric, ginger, and basil, are revered for their sacred qualities (Tarun et al., 2016). Many ancient civilizations, much like those mentioned earlier, placed sig-

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Turmeric is one of the most important spices used today and is one of the food additives used safely all over the world. The reason why turmeric is used as a food additive is its main component, curcuminoids. Curcuminoids show anti-inflammatory, antitumor and antioxidant effects (Pistelli et al., 2012). They measured the content of curcuminoids in plant organs obtained by *in vitro* propagation. Plant parts obtained *in vitro* were examined with curcumin, bis-demethoxy curcumin, demethoxy curcumin by LC-DAD-ESI-MS method. It was observed that a significant amount of curcumin was produced from microrhizomes grown in MS medium containing 0.1 mg/L Kn, 1 mg/L NAA, 6% sucrose, 5% agar and 0.1% activated charcoal, thus success was achieved in the production of curcumin with tissue cultures. These results showed that it is safe to produce *in vitro* (Pistelli et al., 2012).

Tyagi et al. (2007) addressed the cost implications of sucrose as a carbon source and agar as a gelling agent in tissue culture studies conducted for plant production. In an effort to find a solution, the researchers utilized alternative sources, reducing the cost of turmeric plant regeneration and *in vitro* conservation by up to 73%. Isubgol, a colloidal and polysaccharide structure containing over 30% mucilage, was used as a low-cost substitute for agar as a gelling agent (Babbar and Jain, 1998; Ozel, Khawar and Arslan, 2008). In this cost-effective medium, no adverse effects on shoot regeneration and conservation were observed compared to the agar-gelled control medium. C. longa cultures, when conserved in the isabgol-gelled medium, exhibited 33–56% survival for up to 12 months, while the survival rate in the control group was 16%. After one year, the genetic stability of the *in vitro*-preserved plants was evaluated using the RAPD technique, revealing no significant variation in the RAPD profiles of the *in vitro*-preserved seedlings.

In conclusion, the tissue culture production of turmeric and related studies play a crucial role in the sustainability of agriculture, the development of disease-resistant plants, and the enhancement of agricultural production.

REFERENCES

Adebisi, A. A., Olumide, M. D., & Akintunde, A. O. (2021). Nutritive value and phytochemical screening of turmeric and clove as a potential phyto-additive in livestock production. *Nigerian Journal of Animal Science*, *23*(2), 142-152.

Aggarwal, B. B., Ichikawa, H., Garodia, P., Weerasinghe, P., Sethi, G., Bhatt, I. D., ... & Nair, M. G. (2006). From traditional Ayurvedic medicine to modern medicine: identification of therapeutic targets for suppression of inflammation and cancer. *Expert Opinion on Therapeutic Targets*, *10*(1), 87-118.

Aggarwal, B. B., Sundaram, C., Malani, N., Ichikawa, H. (2007). *Curcumin: The Indian solid gold*. In: The molecular targets and therapeutic uses of curcumin in health and disease. Aggarwal B. B., Surh Y. J., & Shishodia, S. (Ed.) Boston: Springer.

Agricultural Research Service, (2019). U.S. Department oF Agrıculture Agricultural Research Service https://fdc.nal.usda.gov/fdc-app.html#/food-details/172231/nutrients Accessed on

12.11.2023, from the address.

Akhtar, S., Sharma, S., Bhuyan, N. R., Shrestha, B., & Baraily, V. R. A. (2023). Systematic review of different analytical methods for major phytoconstituents of turmeric and black pepper. *International Journal of Pharmaceutical Sciences and Research, 14*(6): 2619-2634.

Amalraj, A., Pius, A., Gopi, S., & Gopi, S. (2017). Biological activities of curcuminoids, other biomolecules from turmeric and their derivatives–A review. *Journal of Traditional and Complementary Medicine*, *7*(2), 205-233.

Anık, S. H. (2018). *In vitro* propagation of turmeric *(Curcuma longa L.)* (Doctoral dissertation). Department of Biotechnology, Sher-E-Bangla Agricultural University, Dhaka.

Araujo, C. A. C., & Leon, L. L. (2001). Biological activities of *Curcuma longa* L. *Memórias do Instituto Oswaldo Cruz*, *96*, 723-728.

Atakan, A. (2017). Kilolu ve Obez Bireylerde Zerdeçal Tüketiminin Ağırlık Kaybı ve Kan Lipid Düzeyleri Üzerindeki Etkisinin Değerlendirilmesi. Yüksek Lisans Tezi. Doğu Akdeniz Üniversitesi, Öğretim ve Araştırma Enstitüsü, Beslenme ve Diyetetik*, Gazimağusa, Kuzey Kıbrıs.*

Ayyıldız, S., & Sarper, F. (2019). Antioksidan baharatların Osmanlı saray mutfağındaki yeri. *Karabük Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *9*(1), 363-380.

Babbar, S. B., & Jain, N. (1998). Isubgol'as an alternative gelling agent in plant tissue culture media. *Plant Cell Reports*, *17*, 318-322.

Balachandran, S. M., Bhat, S. R., & Chandel, K. P. S. (1990). *In vitro* clonal multiplication of turmeric (*Curcuma* spp.) and ginger (*Zingiber officinale* Rosc.). *Plant Cell Reports*, *8*, 521-524.

Barati, N., Momtazi-Borojeni, A. A., Majeed, M., & Sahebkar, A. (2019). Potential therapeutic effects of curcumin in gastric cancer. *Journal of Cellular Physiology*, *234*(3), 2317-2328.

Bayraktar, Ö. V., Öztürk, G., & Arslan, D. (2017). Türkiye'de bazı tıbbi ve aromatik bitkilerin üretimi ve pazarlamasındaki gelişmelerin değerlendirilmesi. *Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi*, *26*(2), 216-229.

Bayram, E., Kırıcı, S., Tansı, S., Yılmaz, G., Kızıl, O. A. S., & Telci, İ. (2010). Tıbbi ve aromatik bitkiler üretiminin arttırılması olanakları. *TMMOB Ziraat Mühendisleri Odası, Ziraat Mühendisliği VII. Teknik Kongresi*, *11*, 15.

Bishnoi, M., Chopra, K., & Kulkarni, S. K. (2008). Protective effect of Curcumin, the active principle of turmeric (*Curcuma longa*) in haloperidol-induced orofacial dyskinesia and associated behavioural, biochemical and neurochemical changes in rat brain. *Pharmacology Biochemistry and Behavior, 88*(4), 511-522.

Castiglioni, A. (2019). *A history of medicine* (Vol. 2). Routledge Library Editions.

Chattopadhyay, I., Biswas, K., Bandyopadhyay, U., & Banerjee, R. K. (2004). Turmeric and Curcumin: Biological actions and medicinal applications. *Current Science, 87(1), 44–53.*

Code of Federal Regulations, (2023) - Code of Federal Regulations Title 21. FDA: U.S. Food and Drug Administration. https://www.ecfr.gov/current/title-21 Accessed on 21.11.2023, from the address.

Demirezer, L. Ö., Ersöz, T., Saraçoğlu, İ., Şener, B., Köroğlu, A., & Yalçın, F. N., (2021). *A'dan Z'ye Tıbbi Yağlar ve Aromatik Sular.* İstanbul: Hayykitap.

Eapen, S., & Rao, P. S. (1985). Plant regeneration from immature inflorescence callus cultures of wheat, rye and triticale. *Euphytica*, *34*, 153-159.

El-Hawaz, R. F., Bridges, W. C., & Adelberg, J. W. (2015). *In vitro* growth of *Curcuma longa* L. in response to five mineral elements and plant density in fed-batch culture systems. *Plos One*, *10*(4), 1-13.

Farahani, M. A., Afsargharehbagh, R., Marandi, F., Moradi, M., Hashemi, S. M., Moghadam, M. P., & Balouchi, A. (2019). Effect of aromatherapy on cancer complications: A systematic review. *Complementary therapies in medicine*, *47*, 102169.

Food and Agriculture Organization of The United Nations (2004). https://www.fao.org/fileadmin/user_upload/inpho/docs/Post_Harvest_CompendiumTurmeric.pdf Accessed on 30.10.2023, from the address.

Funk, J. L., Frye, J. B., Oyarzo, J. N., Zhang, H., & Timmermann, B. N. (2010). Anti-arthritic effects and toxicity of the essential oils of turmeric (*Curcuma longa* L.). *Journal of Agricultural and Food Chemistry*, *58*(2), 842-849.

Funk, J. L., Oyarzo, J. N., Frye, J. B., Chen, G., Lantz, R. C., Jolad, S. D., ... & Timmermann, B. N. (2006). Turmeric extracts containing curcuminoids prevent experimental rheumatoid arthritis. *Journal of Natural Products*, *69*(3), 351-355.

Gang, D. R., & Ma, X. Q. (2008). *Ginger and turmeric ancient spices and modern medicines. In Genomics of tropical crop plants* (pp. 299-311). New York, NY: Springer New York.

Ghoneim, A. I., Abdel-Naim, A. B., Khalifa, A. E., & El-Denshary, E. S. (2002). Protective effects of curcumin against ischaemia/reperfusion insult in rat forebrain. *Pharmacological Research*, *46*(3), 273-279.

Ghoreishian, S. M., Maleknia, L., Mirzapour, H., & Norouzi, M. (2013). Antibacterial properties and color fastness of silk fabric dyed with turmeric extract. *Fibers and Polymers*, *14*, 201-207.

Goyal, A. K., Ganguly, K., Mishra, T., & Sen, A. (2010). *In vitro* multiplication of Curcuma longa Linn.-an important medicinal zingiber. *NBU Journal of Plant Sclences, 4*, 21-24.

Gupta, S. C., Sung, B., Kim, J. H., Prasad, S., Li, S., & Aggarwal, B. B. (2013). Multitargeting by turmeric, the golden spice: From kitchen to clinic. *Molecular nutrition & food research*, *57*(9), 1510-1528.

Hakeim, O. A., Abou-Okeil, A., Abdou, L. A. W., & Waly, A. (2005). The influence of chitosan and some of its depolymerized grades on natural color printing. *Journal of applied polymer science*, *97*(2), 559-563.

Hedaoo, S. A., & Chandurkar, P. A. (2019). A review on aromatherapy. *World Journal of Pharmaceutical Research*, *8*(7), 635-651.

Hucklenbroich, J., Klein, R., Neumaier, B., Graf, R., Fink, G. R., Schroeter, M., & Rueger, M. A. (2014). Aromatic-turmerone induces neural stem cell proliferation *in vitro* and *in vivo*. *Stem Cell Research & Therapy*, *5*(4), 1-9.

Hussain, A., Qarshi, I. A., Nazir, H., & Ullah, I. (2012). Plant tissue culture: current status and opportunities. *Recent Advances in Plant in vitro Culture*, *6*(10), 1-28.

Idowu-Adebayo, F., Fogliano, V., & Linnemann, A. (2022). Turmeric-fortified cow and soya milk: Golden milk as a street food to support consumer health. *Foods*, *11*(4), 558.

Istanbul University Medicinal Plant Products Research and Consultation Platform (2023). https://tibuad.istanbul.edu.tr/tr/content/blog/curcuma-longa-(zerdecal) Accessed on 12.11.2023, from the address.

Jackson, J. K., Higo, T., Hunter, W. L., & Burt, H. M. (2006). The antioxidants curcumin and quercetin inhibit inflammatory processes associated with arthritis. *Inflammation Research*, *55*, 168-175.

Jamshidi-Kia, F., Lorigooini, Z., & Amini-Khoei, H. (2017). Medicinal plants: Past history and future perspective. *Journal of Herbmed Pharmacology*, *7*(1), 1-7.

Jian, Y. T., Mai, G. F., Wang, J. D., Zhang, Y. L., Luo, R. C., & Fang, Y. X. (2005). Preventive and therapeutic effects of NF-kappaB inhibitor curcumin in rats colitis induced by trinitrobenzene sulfonic acid. *World Journal of Gastroenterology*, *11*(12), 1747.

Jones, E. A., & Shoskes, D. A. (2000). The effect of mycophenolate mofetil and polyphenolic bioflavonoids on renal ischemia reperfusion injury and repair. *The Journal of Urology*, *163*(3), 999-1004.

Karadağ, R. (2007). *Doğal Boyamacılık*. Ankara: T.C. Kültür ve Turizm Bakanlığı.

Kaynar, H,. Tonus, E., & Uçar Sözmen. (2019). Zerdeçal bitkisinden doğal ve kimyasal mordanlarla elde edilen renkler ve tekstil liflerinde kullanımı. *İdil Sanat ve Dil Dergisi, 63.* 1579-1589

Keville, K., & Green, M. (2012). *Aromatherapy: A Complete Guide to the Healing Art [An Essential Oils Book]*. New York: Crossing Press.

Khanna, N. M. (1999). Turmeric–Nature's precious gift. *Current science*, *76*(10), 1351-1356.

Kinase-STAT, S. T. J. (2002). Curcumin inhibits experimental allergic. *The Journal of Immunology*, *168*, 6506-6513.

Kocaadam, B., & Şanlier, N. (2017). Curcumin, an active component of turmeric (*Curcuma longa*), and its effects on health. *Critical reviews in food science and nutrition*, *57*(13), 2889-2895.

Koo, M. (2017). A bibliometric analysis of two decades of aromatherapy research. *BMC Research*

Notes, *10*(1), 1-9.
Lev-Ari, S., Strier, L., Kazanov, D., Elkayam, O., Lichtenberg, D., Caspi, D., & Arber, N. (2006). Curcumin synergistically potentiates the growth-inhibitory and pro-apoptotic effects of celecoxib in osteoarthritis synovial adherent cells. *Rheumatology*, *45*(2), 171-177.
Li, H. L., Liu, C., De Couto, G., Ouzounian, M., Sun, M., Wang, A. B., ... & Liu, P. P. (2008). Curcumin prevents and reverses murine cardiac hypertrophy. *The Journal of Clinical Investigation*, *118*(3), 879-893.
Liju, V. B., Jeena, K., & Kuttan, R. (2011). An evaluation of antioxidant, anti-inflammatory, and antinociceptive activities of essential oil from *Curcuma longa*. L. *Indian Journal of Pharmacology*, *43*(5), 526.
Lim, H. S., Park, S. H., Ghafoor, K., Hwang, S. Y., & Park, J. (2011). Quality and antioxidant properties of bread containing turmeric (*Curcuma longa* L.) cultivated in South Korea. *Food Chemistry*, *124*(4), 1577-1582.
Lis-Balchin, M. (1997). Essential oils and'aromatherapy': their modern role in healing. *Journal of the Royal Society of Health*, *117*(5), 324-329.
Ma, X., & Gang, D. R. (2006). Metabolic profiling of turmeric (*Curcuma longa* L.) plants derived from *in vitro* micropropagation and conventional greenhouse cultivation. *Journal of Agricultural and Food Chemistry*, *54*(25), 9573-9583.
Mesleki Eğitim ve Öğretim Sisteminin Güçlendirilmesi Projesi, (2008). "T.C. Milli Eğitim Bakanlığı, MEGEP, Bahçecilik, Hidroponik Sistemler", Ankara. https://avys.omu.edu.tr/storage/app/public/hasan.akay/96855/Hidroponik%20Sistemler.pdf
Moghadam, A. R., Tutunchi, S., Namvaran-Abbas-Abad, A., Yazdi, M., Bonyadi, F., Mohajeri, D., ... & Ghavami, S. (2015). Pre-administration of turmeric prevents methotrexate-induced liver toxicity and oxidative stress. *BMC Complementary and Alternative Medicine*, *15*(1), 1-13.
Morimoto, T., Sunagawa, Y., Kawamura, T., Takaya, T., Wada, H., Nagasawa, A., ... & Hasegawa, K. (2008). The dietary compound curcumin inhibits p300 histone acetyltransferase activity and prevents heart failure in rats. *The Journal of Clinical İnvestigation*, *118*(3), 868-878.
Murakami, A., Furukawa, I., Miyamoto, S., Tanaka, T., & Ohigashi, H. (2013). Curcumin combined with turmerones, essential oil components of turmeric, abolishes inflammation-associated mouse colon carcinogenesis. *Biofactors*, *39*(2), 221-232.
Murugan, P., & Pari, L. (2006). Effect of Tetrahydrocurcumin on Lipid Peroxidation and Lipids in Streptozotocin-Nicotinamide-Induced Diabetic Rats. *Basic & Clinical Pharmacology & Toxicology*, *99*(2), 122-127.
Natarajan, C., Bright, J.J. (2002). Curcumin inhibits experimental allergic encephalomyelitis by blocking IL-12 signaling through Janus kinase-STAT pathway in T lymphocytes. *The Journal of Immunology, 168*. 6506-6513
Negi, P. S., Jayaprakasha, G. K., Jagan Mohan Rao, L., & Sakariah, K. K. (1999). Antibacterial activity of turmeric oil: a byproduct from curcumin manufacture. *Journal of Agricultural and Food Chemistry*, *47*(10), 4297-4300.
Onal, A., Tombul, K. C., & Nached, S. (2020). Investigation of dyeing properties of different fabric species with curcuma longa exracts. *Revue Roumaine de Chimie*, *65*(11), 983-988.
Ozel, C.A., Khawar, K. M., Arslan, O. (2008). A comparison of the gelling of isubgol, agar and gelrite on *in vitro* shoot regeneration and rooting of variety Samsun of tobacco (*Nicotiana tabacum* L.). *Scientia Horticulturae 117,* 174–181.
Özel, Ç. A., & Katırcıoğlu H. (2020). *Biyoloji 3*: *Biyoteknolojik Uygulamalar,* Filik İşçen, C. & Aktan, M. B. (Ed.) İstanbul: Lisans Yayıncılık.
Özel, Ç. A., (2017). *Genetik ve Biyoteknoloji*: *Biyoteknolojik Uygulamalar I,* Filik İşçen, C. & Gülnaz, O. (Ed.) İstanbul: Lisans Yayıncılık
Özen, Ö., & İşmal, Ö. E. (2021). Tekstil Tasarımına Ekolojik Bir Yaklaşım: Lyocell Üzerine Doğal Boyama ve Eko Baskı. *Yedi*, (26), 109-130.
Park, C., Moon, D. O., Choi, I. W., Choi, B. T., Nam, T. J., Rhu, C. H., ... & Choi, Y. H. (2007). Curcumin induces apoptosis and inhibits prostaglandin E2 production in synovial fibroblasts of patients with rheumatoid arthritis. *International Journal of Molecular Medicine*, *20*(3), 365-372.

Park, S. Y., Kim, Y. H., Kim, Y., & Lee, S. J. (2012). Aromatic-turmerone attenuates invasion and expression of MMP-9 and COX-2 through inhibition of NF-κB activation in TPA-induced breast cancer cells. *Journal of Cellular Biochemistry*, *113*(12), 3653-3662.

Pistelli, L., Bertoli, A., Gelli, F., Bedini, L., Ruffoni, B., & Pistelli, L. (2012). Production of Curcuminoids in Different *in vitro* Organs of *Curcuma longa*. *Natural Product Communications*, *7*(8), 1934578X1200700819.

Prasad, S., & Aggarwal, B. B. (2011). *Turmeric, the golden spice. Chapter13.* 2nd Edition. Herbal Medicine: Biomolecular and Clinical Aspects.

Prasad, S., Tyagi, A. K., & Aggarwal, B. B. (2014). Recent developments in delivery, bioavailability, absorption and metabolism of curcumin: the golden pigment from golden spice. *Cancer research and treatment: Official journal of Korean Cancer Association*, *46*(1), 2-18.

Prathanturarug, S., Soonthornchareonnon, N., Chuakul, W., Phaidee, Y., & Saralamp, P. (2003). High-frequency shoot multiplication in *Curcuma longa* L. using thidiazuron. *Plant Cell Reports*, *21*, 1054-1059.

Quiles, J. L., Mesa, M. D., Ramírez-Tortosa, C. L., Aguilera, C. M., Battino, M., Gil, Á., & Ramírez-Tortosa, M. C. (2002). Curcuma longa extract supplementation reduces oxidative stress and attenuates aortic fatty streak development in rabbits. *Arteriosclerosis, Thrombosis, and Vascular Biology*, *22*(7), 1225-1231.

Rahimi, A., & Arslan, N. (2012). İran'da Kullanılan Bazı Baharatlar. *Ziraat Mühendisliği*, (359), 54-57.

Ram, A., Das, M., & Ghosh, B. (2003). Curcumin attenuates allergen-induced airway hyperresponsiveness in sensitized guinea pigs. *Biological and Pharmaceutical Bulletin*, *26*(7), 1021-1024.

Rathaur, P., Raja, W., Ramteke, P. W., & John, S. A. (2012). Turmeric: The golden spice of life. *International Journal of pharmaceutical sciences and research*, *3*(7), 1987.

Salvi, N. D., George, L., & Eapen, S. (2000). Direct regeneration of shoots from immature inflorescence cultures of turmeric. *Plant Cell, Tissue and Organ Culture*, *62*, 235-238.

Salvi, N. D., George, L., & Eapen, S. (2001). Plant regeneration from leaf base callus of turmeric and random amplified polymorphic DNA analysis of regenerated plants. *Plant Cell, Tissue and Organ Culture*, *66*, 113-119.

Salvi, N. D., George, L., & Eapen, S. (2002). Micropropagation and field evaluation of micropropagated plants of turmeric. *Plant Cell, Tissue and Organ Culture*, *68*, 143-151.

Sharma, S., Kulkarni, S. K., Agrewala, J. N., & Chopra, K. (2006). Curcumin attenuates thermal hyperalgesia in a diabetic mouse model of neuropathic pain. *European Journal of Pharmacology*, *536*(3), 256-261.

Singh, A., Mishra, M., & Chauhan, S. K. (2011). Nutraceutical and therapeutic value of turmeric (*Curcuma longa* Linn.), a review. *Bioherald: International Journal of Biodiversity & Environment*, *1*(2), 105-114.

Sumanont, Y., Murakami, Y., Tohda, M., Vajragupta, O., Watanabe, H., & Matsumoto, K. (2006). Prevention of kainic acid-induced changes in nitric oxide level and neuronal cell damage in the rat hippocampus by manganese complexes of curcumin and diacetylcurcumin. *Life Sciences*, *78*(16), 1884-1891.

Sunitibala, H., Damayanti, M., & Sharma, G. J. (2001). *In vitro* propagation and rhizome formation in *Curcuma Ionga* Linn. *Cytobıos-Cambrıdge-*, 71-82.

Tarun, S., Ramamurthy, A., Parul, A., & Malvika, S. (2016). Medicinal plants used ın various ındian traditional customs. *International Journal of Ayurvedic and Herbal Medicine*, *6*, 2326-2332.

Tyagi, R. K., Agrawal, A., Mahalakshmi, C., Hussain, Z., & Tyagi, H. (2007). Low-cost media for *in vitro* conservation of turmeric (*Curcuma longa* L.) and genetic stability assessment using RAPD markers. *In Vitro Cellular & Developmental Biology-Plant*, *43*, 51-58.

U.S Department of Agriculture. *Agricultural Research Service.* (2019). "https://www.ars.usda.gov/"

United States Department of Agriculture, (2019). Spices, turmeric, ground – Food Data Central - USDA https://fdc.nal.usda.gov/fdc-app.html#/food-details/172231/nutrients Accessed on

20.11.2023, from the address.
Valdez, P., & Mehrabian, A. (1994). Effects of color on emotions. *Journal of Experimental Psychology: General*, *123*(4), 394.
Varman, R. (2017). Curry. *Consumption Markets & Culture*, *20*(4), 350-356.
Vecchione, R., Quagliariello, V., Calabria, D., Calcagno, V., De Luca, E., Iaffaioli, R. V., & Netti, P. A. (2016). Curcumin bioavailability from oil in water nano-emulsions: *İn vitro* and in vivo study on the dimensional, compositional and interactional dependence. *Journal of Controlled Release*, *233*, 88-100.
Vlietinck, A. J., De Bruyne, T., Apers, S., & Pieters, L. A. (1998). Plant-derived leading compounds for chemotherapy of human immunodeficiency virus (HIV) infection. *Planta Medica*, *64*(02), 97-109.
Vyas. K., (2015). The Cure is in the Roots: Turmeric. *Nutritional Disorders & Therapy. 5*(3), 1-6.
Wang, M.,& Ha, Y. (2007). An electrochemical approach to monitor pH change in agar media during plant tissue culture. *Biosensors and Bioelectronics*, *22*(11), 2718-2723.
Wiart, C. (2007). *Ethnopharmacology of medicinal plants: Asia and the Pacific*. USA: Humano Press Springer Science & Business Media, Humana Press.
World Health Organization. (2000). *General guidelines for methodologies on research and evaluation of traditional medicine*. Geneva: World Health Organization.
Xu, Y., Ku, B. S., Yao, H. Y., Lin, Y. H., Ma, X., Zhang, Y. H., & Li, X. J. (2005). The effects of curcumin on depressive-like behaviors in mice. *European Journal of Pharmacology*, *518*(1), 40-46.
Yalçın, A. (2000). *Baharat Dünyası, Baharat ve Popüler Otlar Ansiklopedisi*. İstanbul: Geçit Kitabevi.
Zapata, E. V., Morales, G. S., Lauzardo, A. N. H., Bonfil, B. M., Tapia, G. T., Sánchez, A. D. J., ... & Aparicio, A. J. (2003). *İn vitro* regeneration and acclimatization of plants of turmeric (*Curcuma longa* L.) in a hydroponic system. *Biotecnología Aplicada*, *20*, 25-31
Zbarsky, V., Datla, K. P., Parkar, S., Rai, D. K., Aruoma, O. I., & Dexter, D. T. (2005). Neuroprotective properties of the natural phenolic antioxidants curcumin and naringenin but not quercetin and fisetin in a 6-OHDA model of Parkinson's disease. *Free Radical research*, *39*(10), 1119-1125.

CHAPTER 4

ONE HEALTH: LOSS OF BIODIVERSITY

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INTRODUCTION

Zoonotic infectious diseases, which emerged in the late twentieth century and mostly originate from wildlife animals, reveal that animal, human and ecosystem health are interrelated. A multidisciplinary approach involving animal, human and ecosystem health has been developed to conduct risk assessments, take preventive measures and develop control plans. Following the emergence of various viral diseases such as bird flu and Zika virus, the interrelatedness of animal, human and ecosystem health has become even more important. The "One Health" concept was developed in 2004, based on the "One Medicine" concept of human and veterinary medicine (Destoumieux-Garzón et al., 2018; Mackenzie and Jeggo, 2019).

According to United States Centers for Disease Control and Prevention, One Health means "a collaborative, multisectoral, and transdisciplinary approach—working at the local, regional, national, and global levels—with the goal of achieving optimal health outcomes recognizing the interconnection between people,

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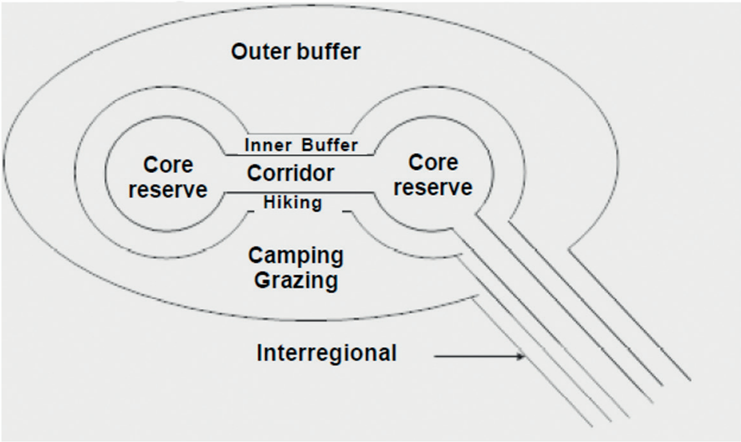

Figure 5. Protected area template (Nigam, 2019)

CONCLUSION

This review examined biodiversity loss, one of the ecosystem health components within the concept of One Health. The definition of biodiversity, the relationships between species, the causes of biodiversity loss, especially its effects on ecosystem health, and the measures taken to prevent biodiversity loss are mentioned. Today, when biodiversity is rapidly decreasing day by day, our understanding and conservation efforts in this context need to be further strengthened. Future studies should take a comprehensive approach to more deeply understand the relationships between biodiversity sustainability, ecosystem services, and human health.

REFERENCES

Achieng A.O., Arhonditsis G.B., Mandrak N., et al. (2023). Monitoring biodiversity loss in rapidly changing Afrotropical ecosystems: an emerging imperative for governance and research. Philosophical Transactions of the Royal Society B.378(1881), 20220271.

Alcamo J., Van Vuuren D., Cramer W., et al. (2005). Changes in ecosystem services and their drivers across the scenarios. Ecosystems and human well-being, 2005; 297-373.

Anonymousa (2023). Accessed date: 01.12.2023. Retrieved from https://www.cdc.gov/onehealth/index.html#:~:text=One%20Health%20is%20a%20collaborative,plants%2C%20and%20their%20shared%20environment.

Anonymousb. (2023). Accessed date: 01.12.2023. Retrieved from https://www.cdc.gov/onehealth/basics/index.html

Araujo M.B., Pearson R.G., Thuiller W., et al. (2005). Validation of species-climate impact models under climate change. Global Change Biology.11(9):1504–1513.

Arslan P., Ozeren S.C. (2022). Physiological and histopathological alterations in Capoeta baliki and Squalius pursakensis after caused by some environmental pollutants. Environmental Monitoring and Assessment.194, 183. doi: 10.1007/s10661-022-09830-y

Baillie J.E.M., Hilton-Taylor C., Stuart S.N. (2004) IUCN Red List of Threatened Species. A Global Species Assessment. Gland, Switz.: IUCN

Balmford A., Green R.E., Jenkins M. (2003). Measuring the changing state of nature. Trends in Ecology and Evolution. 2003;18(7):326–30.
Barnosky A.D., Matzke N., Tomiya S., et al. (2011). as the Earth's sixth mass extinction already arrived? Nature 471, 51–57.
Braverman I. (2014). Conservation without nature: the trouble with in situ versus ex situconservation. Geoforum. 47-57.
Burkhart, E. (2007). In Situ Conservation of Wild Plant Species: A Critical Global Review of Good Practices. Economic Botany.61(2):205-206.
Butchart S.H.M., Walpole M., Collen B., et al. (2010). Global biodiversity: Indicators of recent declines. Science 328, 1164–1168.
Cardinale B.J., Duffy J.E., Gonzalez A., et al. (2012). Biodiversity loss and its impact on humanity. Nature.486(7401), 59-67.
Carpenter S.R., Mooney H.A., Agard J., et al. (2009). Science for managing ecosystem services: beyond the Millennium Ecosystem Assessment. Proceedings of the National Academy of Sciences of the United States of America.106(5):1305–12.
Ceballos G., Ehrlich P.R. (2009). Mammal population losses and the extinction crises. Proceedings of the National Academy of Sciences of the United States of America.106, 3841–3846.
Ceballos G., Garcia A., Ehrlich P.R. (2010). The sixth extinction crisis: Loss of animal populations and species. Journal of Cosmology.8, 1821–1831.
Clarke H. (2007). Conserving Biodiversity in the Face of Climate Change. Agenda.14(2):157-170.
Demirsoy A. (2005). Yaşamın Temel Kuralları. (15) Ankara: Meteksan Yayınevi; 2005.
Destoumieux-Garzón D., Mavingui P., Boetsch G., et al. (2018). The one health concept: 10 years old and a long road ahead. Frontiers in Veterinary Science.5, 14.
Dulvy N.K, Rogers S., Jennings S., et al. (2008). Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas. Journal of Applied Ecology. 45(4):1029-1039.
Duraiappah A., Naheem S., Agardy T., et al. (2005). Ecosystems and Human Well-Being: Biodiversity Synthesis. Washington, DC: World Resour. Inst.
Elmqvist T., Maltby E., Barker T., et al. (2010). Biodiversity, ecosystems and ecosystem services. Ecological and Economic Foundations.
Fahrig L. (2013). Effects of Habitat Fragmentation on Biodiversity. Annual Review of Ecology, Evolution, and Systematics. 34:487–515.
Fischlin A., Midgley G.F., Price J., et al. (2007). Ecosystems, their properties, goods and services. In Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPCC, ed. ML Parry, OF Canziani, JP Palutikof, PJ van der Linden, CE Hanson, pp. 211–72. Cambridge, UK: Cambridge Univ. Press
Hammond G. (2006). People, planet and prosperity': the determinants of humanity's environmental footprint. Natural Resources Forum. 2006;30, 27-36.
Holdren J.P., Ehrlich P.R. (1974). Human population and the global environment. American scientist. 62(3):282–292.
Holland J.N., Bronstein J.L. (2008). Mutualism. Encyclopedia of Ecology.2485-2491. doi:10.1016/b978-008045405-4.00673-x
Hughes A.C., Tougeron K., Martin D.A., et al. (2023). Smaller human populations are neither a necessary nor sufficient condition for biodiversity conservation. Biological Conservation. 2023; 277, 109841.
Kell, N.M. (2009). Commission On Genetic Resources for Food And Agriculture. FAO.
Ketenoglu O. (2002). Genel Biyoloji-Ekoloji. Ankara: Palme Yayınevi.
Krauss J., Bommarco R., Guardiola M., et al. (2010). Habitat fragmentation causes immediate and time–delayed biodiversity loss at different trophic levels. Ecology letters,13(5):597–605.
Kumari R., Deepali A., Bhatnagar S. (2021). Biodiversity Loss: Threats and Conservation Strategies. International Journal of Pharmaceutical Sciences Review and Research. 2021;242-254.
Kurt H. (2017). Bıodıversıty At The Crossroads Of Envıronmental Issues. Suleyman Demirel University The Journal of Faculty of Economics and Administrative Sciences. 2017;22(3):825-837.
Leadley P.W., Pereira H.M., Alkemade R., et al. (2010). Biodiversity Scenarios: Projections of 21st Century Change in Biodiversity and Associated Ecosystem Services. Montreal: Secr. Conv. Biol. Divers.132 pp

Loewe L., Hill W. (2010). The population genetics of mutations: good bad and indifferent. *Philosophical Transactions of the Royal Society B: Biological Sciences.;365*,1153 – 1167.

Mackenzie J.S., Jeggo M. (2019). The One Health Approach—Why Is It So Important? Tropical Medicine and Infectious Disease. 4, 88. https://doi.org/10.3390/tropicalmed4020088

McMillan N.A., Fuhlendorf S.D., Davis C.A., et al. (2023). A plea for scale, and why it matters for invasive species management, biodiversity and conservation. Journal of Applied Ecology. doi:10.1111/1365-2664.14411

MEA (Millennium Ecosystem Assessment). (2005). Ecosystems and human wellbeing: Synthesis. Washington, DC: Island Press. Retrieved May 1, 2018, from http://www.millenniumassessment.org/documents/document.356.aspx.pdf

Mikula P., Hadrava J., Albrecht T., et al. (2018). Large-scale assessment of commensalistic-mutualistic associations between African birds and herbivorous mammals using internet photos. PeerJ.6: e4520.

Moreira F., Russo D. (2007). Modelling the impact of agricultural abandonment and wildfires on vertebrate diversity in Mediterranean Europe. Landscape Ecology.22(10):1461–76.

Munoz-Blanco J.V.. (2015). "Biodiversity for the present and future of humanity: A suggestion fort the SDG process. Earth System Governance Project.

Navarro L., Pereira H.M. (2012). Rewilding abandoned landscapes in Europe. Ecosystems. 15:900–912.

Nigam A. (2019). Biodiversity: Threats and Conservation. A. Nigam içinde, Biodiversity (s. 158). Indira Gandhi National Open University.

Panwar R., Ober H., Pinkse J. (2023). The uncomfortable relationship between business and biodiversity: Advancing research on business strategies for biodiversity protection. Business Strategy and the Environment.32(5): 2554-2566.

Paul, B. (2008). A history of the concept of sustainable development: literature review. The Annals of The University of Oradea, s. 581.

Pereira H.M., Navarro L.M., Martins I.S. (2012). Global biodiversity change: the bad, the good, and the unknown. Annual Review of Environment and Resources.37.

Pimm L. (2007). Biodiversity: Climate Change or Habitat Loss-Which Will Kill More Species? Current Biology.18(3):117-119.

Romanelli C., Cooper H.D., de Souza Dias B.F. (2014). The integration of biodiversity into One Health. Revue Scientifique et Technique. Aug;33(2):487-96. doi: 10.20506/rst.33.2.2291. PMID: 25707179.

Scholes R.J, Gill M.J., Costello M.J., et al. (2017). Working in Networks to Make Biodiversity Data More Available.

Singh R.S.I.A. (2017). Medicinal plants in ex-situ conservation and its therapeutic in mine impacted lands of dry tropical forests of Jharkhand, India. Eurasian Journal of Forest Science, 44-69.

Tan A. (2009). In Situ (On Farm) Conservatıon of Land Races From Transıtıonal Zone In Turkey. Anadolu, Journal of Aari, 2009; 1-13.

The Economics of Ecosystems and Biodiversity (TEEB). (2010). Mainstreaming the Economics of Nature: A Synthesis of the Approach, Conclusions and Recommendations of TEEB. Geneva: TEEB.

Türkeş M. (2007). Küresel iklim değişikliği nedir? Temel kavramlar, nedenleri, gözlenen ve öngörülen değişiklikler. 1. Türkiye İklim Değişikliği Kongresi (TİKDEK 2007), 11-13 April, İstanbul, (2007). (p. 11-13).

UN. (2023). Global Issues Population. UN: https://www.un.org/en/global-issues/population

United Nations. (2013). Convention on biological diversity. United Nations, Rio de Janeiro.

van Vuuren D.P., Sala O.E., Pereira H.M. (2006). The future of vascular plant diversity under four global scenarios. Ecology and Society.11(2):25.

Vie J.C., Hilton-Taylor C., Stuart S.N. (2009). Wildlife in a Changing World: An Analysis of the 2008 IUCN Red List of Threatened Species. Gland, Switz.: IUCN

Wackernagel M., L. L. (1999). Evaluating the use of natural capital with the ecological footprint: applications in sweden and subregions. Ambio.28(7) s. 604-612.

Zahoor I., Mushtaq A. (2023). Water pollution from agricultural activities: A critical global review. International Journal of Chemical and Biochemical Sciences. 23(1): 164-176.

CHAPTER 5

EFFECTS OF ANTIFOULING SUBSTANCES ON AQUATIC ORGANISMS

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INTRODUCTION

Organisms such as mussels, algae and bacteria that live in aquatic ecosystems cause damage by adhering to vehicles such as boats, ships, oil wells, or piers (Figure 1). The adhesion of these organisms to an area is a fast and complex process (Li et al., 2023). In the first stage, organic substances such as proteins, polysaccharides, and inorganic substances adhere to a solid surface immersed in water, forming a thin film layer. This substrate film layer is a prerequisite for the adsorption of microorganisms (Jain and Bhosl, 2009). In the second stage, bacteria or diatoms adhere to the substrate film layer and form the biofilm layer. In the third stage, microfouling, as a result of the excessive proliferation of microorganisms in the biofilm layer, the biofilm is fixed and prepared for adhesion to different organisms. In the fourth and final stage, macrofouling, different species adhere to the membrane surface. Therefore, a biological pollution occurs (Li et al., 2023) (Figure 2).

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CONCLUSION

The effects of antifouling paints, which have an important place especially in the marine industry, on aquatic organisms are shown in this review. The fact that organotin compounds are extremely toxic and show both acute and chronic toxic effects on aquatic organisms has led to these substances being banned by international agreements. However, studies have revealed the acute toxic effects of alternative antifouling substances, the use of which has started to increase, and harmful effects on non-target species have also been observed in acute and chronic exposure studies. For this reason, some alternative antifouling agents are also banned. In the long term, the effects of new or existing alternative antifouling substances on non-target aquatic species are of concern.

Acknowledgement

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REFERENCES

Arslan P., Gül G., & Günal A.Ç. (2023). How do biocidals affect the non-target marine organisms: the short-term effects of antifouling agent sodium pyrithione on Mediterranean mussels (*Mytilus galloprovincialis*, Lamark 1819). *Environmental Science and Pollution Research*, 30, 118332–118340. doi: 10.1007/s11356-023-30611-8

Bao V.W., Leung K.M., Qiu J.W., et al. (2011). Acute toxicities of five commonly used antifouling booster biocides to selected subtropical and cosmopolitan marine species. *Marine Pollution Bulletin*, 62(5), 1147-1151. doi: 10.1016/j.marpolbul.2011.02.041

Bourdon C, Cachot J, Gonzalez P, et al. (2023). Characterization of the bioaccumulation and toxicity of copper pyrithione, an antifouling compound, on juveniles of rainbow trout. *bioRxiv*, 2023-01.

Bourdon C, Couture P, Gourves P.Y., et al. (2023). Comparison of the accumulation and effects of copper pyrithione and copper sulphate on rainbow trout larvae. *Environmental Toxicology and Pharmacology*, 104, 104308. doi: 10.1016/j.etap.2023.104308

Costa B.V.M.D., Yogui G.T., & Souza-Santos L.P. (2014). Acute toxicity of tributyltin on the marine copepod *Tisbe biminiensis*. *Brazilian Journal of Oceanography*, 62, 65-69.

Dimitriou P., Castritsi-Catharios J., & Miliou H. (2003). Acute toxicity effects of tributyltin chloride and triphenyltin chloride on gilthead seabream, *Sparus aurata* L., embryos. *Ecotoxicology and Environmental Safety*, 54(1), 30-35. doi: 10.1016/s0147-6513(02)00008-8

doi: 10.1002/aoc.886

Duchet C., Mitchell C.J., McIntyre J.K., et al. (2023). Chronic toxicity of three formulations of neonicotinoid insecticides and their mixture on two daphniid species: *Daphnia magna* and *Ceriodaphnia dubia*. *Aquatic Toxicology*,254, 106351. doi: 10.1016/j.aquatox.2022.106351

Erdoğan K. (2023). Determination of acute toxicity of sodium pyrithione and its exposure effects on antioxidant enzymes activity, immune status, and histopathological changes in common carp. *Chemistry and Ecology*, 39(4), 376-392.

Estêvão M.D. (2023). Aquatic Pollutants: Risks, Consequences, Possible Solutions and Novel Testing Approaches. *Fishes*, 8(2), 97. doi:10.3390/fishes8020097

Ferreira N.G.D.C., Chessa A., Abreu I.O., et al. (2023). Toxic relationships: Prediction of TBT's affinity to the ecdysteroid receptor of *Triops longicaudatus*. *Toxics*, 11(11), 937. doi: 10.3390/toxics11110937

Gerhardt A., Schäfer M., Blum T., et al. (2020). Toxicity of microplastic particles with and without adsorbed tributyltin (TBT) in *Gammarus fossarum* (Koch, 1835). *Foundamental and Applied Limnology*, 194(1), 57-65.

Günal A.Ç., Arslan P., İpiçürük N., et al. (2022). Determination of endocrine disrupting effects of the antifouling pyrithiones on zebrafish (*Danio rerio*). *Energy, Ecology and Environment*, 7(5), 523-531.

Günal A.Ç., Katalay S., Erkmen B., et al. (2018). Antifouling bakır pritiyonun midye (*Mytilus galloprovincialis*)'de toplam hemosit sayıları üzerine etkilerinin belirlenmesi. *Ege Journal of Fisheries and Aquatic Sciences*, 35(1), 15-17.

Jain A, & Bhosle N.B. (2009). Biochemical composition of the marine conditioning film: implications for bacterial adhesion. *Biofouling*, 2009;25(1):13-19. doi: 10.1080/08927010802411969

Katalay S, Guner A, Dagdeviren M, et al. (2022). Oxidative stress-induced apoptotic changes after acute exposure to antifouling agent zinc pyrithione (ZnPT) in *Mytilus galloprovincialis* Lamark (Mediterranean mussels) tissues. *Chemistry and Ecology*, 38(4), 356-373.

Khondee P., Srisomsap C., Chokchaichamnankit D., et al. (2016). Histopathological effect and stress response of mantle proteome following TBT exposure in the Hooded oyster *Saccostrea cucullata*. *Environmental Pollution*, 218, 855-862. doi: 10.1016/j.envpol.2016.08.011

Kyung-Nam H. (2004). Acute toxicity of dissolved inorganic metals, organotins and polycyclic aromatic hydrocarbons to puffer fish, *Takifugu obscurus*. *Environmental Analysis Health and Toxicology*, 2004; 19(2), 141-151.

Lee J.S., Lee K.T., & Park G.S. (2005). Acute toxicity of heavy metals, tributyltin, ammonia and polycyclic aromatic hydrocarbons to benthic amphipod *Grandidierella japonica*. *Ocean Science Journal*, 40, 61-66.

Lee S, Haque M.N., Lee D.H., et al. (2023). Comparison of the effects of sublethal concentrations of biofoulants, copper pyrithione and zinc pyrithione on a marine mysid-A multigenerational study. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, 271, 109694. doi: 10.1016/j.cbpc.2023.109694

Li P., & Li Z.H. (2020). Environmental co-exposure to TBT and Cd caused neurotoxicity and thyroid endocrine disruption in zebrafish, a three-generation study in a simulated environment. *Environmental Pollution*, 259, 113868. doi: 10.1016/j.envpol.2019.113868

Li X., Liu G., Wang Z., et al. (2023). Ensemble multiclassification model for aquatic toxicity of organic compounds. *Aquatic Toxicology*, 2023; 255, 106379. doi: 10.1016/j.aquatox.2022.106379

Li Y, Huang X, Ge N, et al. (2023). Occurrence of organotin compounds in food: increasing challenge of phenyltin compounds. *Journal of Environmental Science and Health, Part B*, 1-6. doi: 10.1080/03601234.2023.2278385

Li Z., Liu P., Chen S., et al. (2023). Bioinspired marine antifouling coatings: Antifouling mechanisms, design strategies and application feasibility studies. *European Polymer Journal*, 111997. doi: 10.1016/j.eurpolymj.2023.111997

Li Z.H., Li P., & Shi Z.C. (2015). Chronic exposure to tributyltin induces brain functional damage in juvenile common carp (*Cyprinus carpio*). *PLoS One*, 10(4), e0123091. doi: 10.1371/journal.pone.0123091

Li Z.H., Li P., & Shi Z.C. (2015). Responses of the hepatic glutathione antioxidant defense system and related gene expression in juvenile common carp after chronic treatment with tributyltin. *Ecotoxicology*, 24, 700-705. doi: 10.1007/s10646-014-1416-2

Li Z.H., Li P., & Shi Z.C. (2016). Chronic effects of tributyltin on multiple biomarkers responses in juvenile common carp, *Cyprinus carpio*. *Environmental Toxicology*, 31(8), 937-944. doi: 10.1002/tox.22103

Liu L., Du R.Y., Jia R.L., et al. (2023). Micro (nano) plastics in marine medaka: Entry pathways and cardiotoxicity with triphenyltin. *Environmental Pollution*, 123079. doi: 10.1016/j.envpol.2023.123079

Luo H.W., Lin M., Bai X.X., et al. (2023). Water quality criteria derivation and tiered ecological risk evaluation of antifouling biocides in marine environment. *Marine Pollution Bulletin*, 187, 114500. doi: 10.1016/j.marpolbul.2022.114500

Martínez M.L., Piol M.N., Sbarbati Nudelman N., et al. (2017). Tributyltin bioaccumulation and toxic effects in freshwater gastropods *Pomacea canaliculata* after a chronic exposure: field and laboratory studies. *Ecotoxicology*, 26, 691-701. doi: 10.1007/s10646-017-1801-8

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 91590, Cybutryne. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Cybutryne.

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 3120, Diuron. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Diuron.

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 26041, Pyrithione Zinc. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Pyrithione-Zinc.

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 183559, Tralopyril. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Tralopyril.

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 68602, Medetomidine. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Medetomidine.

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 19658, Sodium Omadine. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Sodium-Omadine.

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 15910, Chlorothalonil. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Chlorothalonil.

National Center for Biotechnology Information (2023). PubChem Compound Summary for CID 84692, Copper Omadine. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Copper-Omadine.

National Center for Biotechnology Information (2023a). PubChem Compound Summary for CID 3032732, Tributyltin. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Tributyltin.

National Center for Biotechnology Information (2023b). PubChem Compound Summary for CID 5357402, Triphenyltin hydride. Retrieved December 12, 2023 from https://pubchem.ncbi.nlm.nih.gov/compound/Triphenyltin-hydride.

Paçal E, Gümüş B.A., Günal A.Ç., et al. (2022). Oxidative stress response as biomarker of exposure of a freshwater invertebrate model organism (*Unio mancus* Lamarck, 1819) to antifouling copper pyrithione. *Pesticides and Phytomedicine*, 37(2), 63-76.

Panagoula B, Panayiota M, & Iliopoulou-Georgudaki J. (2002). Acute toxicity of TBT and Irgarol in *Artemia salina*. *International Journal of Toxicology*, 21(3), 231-233. doi: 10.1080/10915810290096360

Paz-Villarraga C.A., Castro Í.B., & Fillmann G. (2022). Biocides in antifouling paint formulations currently registered for use. *Environmental Science and Pollution Research*, 1-12. doi: 10.1007/s11356-021-17662-5

Perina F.C, Abessa D.M.D.S., Pinho G.L.L., et al. (2023). Toxicity of antifouling biocides on planktonic and benthic neotropical species. *Environmental Science and Pollution Research*, 30(22), 61888-61903. doi: 10.1007/s11356-023-26368-9

Sharma S.N., Nayak S., Pradhan S.P., et al. (2023). Effect of anti-fouling organotin compound (TBTCl) and the ameliorative role of spirulina on *Lamellidens marginalis*. *Environmental Quality Management*. doi: 10.1002/tqem.22073

Shu S.N., Jiang R.T., Yin J., et al. (2023). Characteristics, sources and health risks of organotin compounds in marine organisms from the seas adjacent to the eastern ports of China. *Regional Studies in Marine Science*, 61, 102929. doi: 10.1016/j.rsma.2023.102929

Sousa A., Genio L., Mendo S., et al. (2005). Comparison of the acute toxicity of tributyltin and copper to veliger larvae of *Nassarius reticulatus* (L.). *Applied Organometallic Chemistry*, 19(3), 324-328.

Takahashi K. (2009). Release Rate of Biocides from Antifouling Paints. Arai, T., Harino, H., Ohji, M., & Langston, W. J. (Eds.). *Ecotoxicology of Antifouling Biocides* (p. 315). Tokyo: Springer Japan.

Třešňáková N., Günal A.Ç., Başaran Kankılıç G., et al. (2020). Sub-lethal toxicities of zinc pyrithione, copper pyrithione alone and in combination to the indicator mussel species *Unio crassus* Philipsson, 1788 (Bivalvia, Unionidae). *Chemistry and Ecology*, 36(4), 292-308,

Wang S., Chen Y., Gu C., et al. (2023). Antifouling coatings fabricated by laser cladding. *Coatings*, 13(2), 397. doi: 10.3390/coatings13020397

Wang X, Li P, He S, et al. (2022). Effects of tralopyril on histological, biochemical and molecular impacts in Pacific oyster, *Crassostrea gigas*. *Chemosphere*, 289, 133157. doi: 10.1016/j.chemosphere.2021.133157

Winder C., Azzi R, & Wagner D. (2005). The development of the globally harmonized system (GHS) of classification and labelling of hazardous chemicals. *Journal of Hazardous Materials*, 125(1-3), 29-44. doi: 10.1016/j.jhazmat.2005.05.035

Yi X., Bao V.W., & Leung K.M. (2017). Binary mixture toxicities of triphenyltin with tributyltin or copper to five marine organisms: Implications on environmental risk assessment. *Marine Pollution Bulletin*, 124(2), 839-846. doi: 10.1016/j.marpolbul.2017.02.031

Yılmaz Sezer İ, Koçak G, Tural R, et al. (2023). Environmental pollutant sodium omadine: toxic effects in zebra fish (*Danio rerio*). *Toxicology Mechanisms and Methods*, 1-6. doi: 10.1080/15376516.2023.2279717

Yun Y.J., Kim S.A., Kim J., et al. (2023). Acute and Chronic Effects of the Antifouling Booster Biocide Diuron on the Harpacticoid Copepod *Tigriopus japonicus* Revealed through Multi-Biomarker Determination. *Journal of Marine Science and Engineering*, 11(10), 1861.

Zhang J., Zhang C., Ma D., et al. (2017). Lipid accumulation, oxidative stress and immune-related molecules affected by tributyltin exposure in muscle tissues of rare minnow (*Gobiocypris rarus*). *Fish & Shellfish Immunology*, 71, 10-18. doi: 10.1016/j.fsi.2017.09.066

Zhao C.S., Fang D.A., & Xu D.P. (2020). Toll-like receptors (TLRs) respond to tributyltin chloride (TBT-Cl) exposure in the river pufferfish (*Takifugu obscurus*): Evidences for its toxic injury function. *Fish & Shellfish Immunology*, 99, 526-534. doi: 10.1016/j.fsi.2020.02.050

CHAPTER 6

Anti-Quorum Sensing Activity and Anti-Biofilm Potential of Extracts Isolated from Fish Associated Bacteria

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INTRODUCTION

Antibiotic-resistant bacterial strains have emerged due to the misuse of antibiotics, which are used to treat and prevent diseases. Misuse of antibiotics results in selection pressure, leading to drug resistance (Chu et. al., 2014).

As multidrug-resistant infections increase, antibacterial therapies become less effective (Rama Devi et al., 2016). The scientific community is concerned about developing novel antimicrobial agents and studying their mechanisms of action as potential precursors to therapeutic compounds to address this widespread issue. Bacterial quorum sensing (QS) is an intercellular signals and gene control process that relies on density of population for cell-to-cell communication.

The cell density-dependent bacterial communication system is used to regulate the virulence phenotype that contributes to the pathogenicity of many pathogenic microorganisms (Rajkumari et al., 2019).

In collaborative activities such as colony formation and motility, many bacteria release metabolic intermediates that are considered signals, which have low molecular weights.

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REFERENCES

Balasubramanian S, Othman E.M., Kampik D, Stopper H, Hentschel U, Ziebuhr W, Oelschlaeger T.A., Abdelmohsen U.R. (2017). Marine sponge-derived Streptomyces sp. SBT343 extract inhibits Stpahylococcal biofilm formation. *Front Microbiol*. (8) :236. doi:10.3389/fmicb.2017.00236.

Camesi, A.B.R., Lukito, A., Waturangi, D.E., Kwan, H.J. (2016). Screening of Antibiofilm Activity from Marine Bacteria against Pathogenic Bacteria. *Microbiology Indonesia*, 10(3): 87-94. doi: 10.5454/mi.10.3.2

Chu W., Z., Shuxin, Zhu W., Zhuang X. (2014). Quorum quenching bacteria *Bacillus* sp. QSI-1 protect zebrafish (Danio rerio) from *Aeromonas hydrophila* infection. *Scientific Reports*, 4: 5446. doi: 10.1038/srep05446

Djordjevic D, Wiedmann M, McLandsborough L.A. (2002). Microtiter plate assay for assessment of Listeria monocytogenes biofilm formation. *Appl Environ Microbiol.* 68 (6): 2950–8. doi: 10.1128/aem.68.6.2958.2002.

El-Kurdi N, Abdulla H, Hanora A. (2021). Anti-quorum sensing activity of some marine bacteria isolated from different marine resources in Egypt. *Biotechnol Lett.* 43 (2): 455–468. doi:10.1007/s10529-020-03020-x

Eryılmaz M, Kart D, Gürpınar S.S. (2019). Investigation of Antibiofilm Activities of Lactobacillus sp. Metabolites Isolated from Vaginal Flora. *Türk Mikrobiyoloji Cem Derg.* 49(3):169-174 doi:10.5222/TMCD.2019.169

Fazeli N, Jalali S.A.H., Naeemi A.S. et al. (2022). In vitro and in vivo antibacterial activity of sea anemone-isolated *Vibrio parahaemolyticus* against *Yersinia ruckeri. Aquacult Int*.; 30, 2453–2475. doi:10.1007/s10499-022-00913-8

Gopal R, Lee J.H., Kim Y.G., Kim M.S., Seo C.H., Park Y. (2013). Anti-microbial, anti-biofilm activities and cell selectivity of the NRC-16 peptide derived from witch flounder, Glyptocephalus cynoglossus. *Mar Drugs*. 28; 11(6): 1836-52. doi: 10.3390/md11061836.

Hong X, Wang Y, Chen S, Zhu J. (2021). Efficacy of ten structurally related essential oil components on anti-biofilm and anti-quorum sensing against fish spoilers *Pseudomonas* and *Aeromonas. J. Aquat. Food Prod. Technol.* 30 (4): 462–473.doi: 10.1080/10498850.2021.1895943

Khan MS, Zahin M, Hasan S, Husain F.M., Ahmad I. (2009). Inhibition of quorum sensing regulated bacterial functions by plant essential oils with special reference to clove oil. *Lett Appl Microbiol.* 49(3): 354-60. doi: 10.1111/j.1472-765X.2009.02666.x.

Koh K.H., Tham F.Y. (2011). Screening of traditional Chinese medicinal plants for quorum-sensing inhibitors activity. *J Microbiol Immunol Infect.* 44(2):144-8. doi: 10.1016/j.jmii.2009.10.001.

Kostakioti M, Hadjifrangiskou M, Hultgren S.J. (2013). Bacterial biofilms: development, dispersal, and therapeutic strategies in the dawn of the postantibiotic era. *Cold Spring Harb Perspect Med*. 3(4): a010306. doi: 10.1101/cshperspect.a010306.

Lau P.C., Lindhout T., Beveridge T.J., Dutcher J.R., Lam J.S. (2009). Differential lipopolysaccharide core capping leads to quantitative and correlated modifications of mechanical and structural properties in Pseudomonas aeruginosa biofilms. *J Bacteriol*. 191(21): 6618-31. doi: 10.1128/JB.00698-09.

Liu H, Wang Y, Cao J, Jiang H, Yao J, Gong G. et al. (2020). Antimicrobial activity and virulence attenuation of citral against the fish pathogen *Vibrio alginolyticus*. *Aquaculture,* 515(15): 734578. doi: 10.1016/j.aquaculture.2019.734578

Patel M, Ashraf M.S., Siddiqui A.J., Ashraf S.A. (2020). Sachidanandan M, Snoussi M, Adnan M, Hadi S. Profiling and Role of Bioactive Molecules from *Puntius sophore* (Freshwater/Brackish Fish) Skin Mucus with Its Potent Antibacterial, Antiadhesion, and Antibiofilm Activities. *Biomolecules.* 17; 10(6): 920. doi: 10.3390/biom10060920.

Raissa G, Waturangi D.E., Wahjuningrum D. (2020). Screening of antibiofilm and anti-quorum sensing activty of Actinomycetes isolates extracts against aquaculture pathogenic bacteria. *BMC Microbiol.* 12; 20(1): 343. doi: 10.1186/s12866-020-02022-z.

Rajkumari J, Borkotoky S, Reddy D, Kumavath S.K.R., Murali A, Suchiang K, Busi S. (2019). Anti-quorum Mohanty sensing and anti-biofilm activity of 5-hydroxymethyl furfural against *Pseudomonas aeruginosa* PAO1: Insights from in vitro, in vivo and in silico studies. *Microbiological Research*. 226, 19-26. doi: 10.1016/j.micres.2019.05.001

Rama Devi K, Srinivasan R, Kannappan A, Santhakumari S, Bhuvaneswari M, Rajasekar P, Prabhu N.M., Veera Ravi A. (2016). In vitro and in vivo efficacy of rosmarinic acid on quorum sensing mediated biofilm formation and virulence factor production in *Aeromonas hydrophila. Biofouling.* 32(10): 1171-1183. doi: 10.1080/08927014.2016.

Rendueles O, Kaplan J.B., Ghigo J. (2012). MAntibiofilm polysaccharides. *Environ Microbiol*. 15: 334-346. doi:10.1111/j.1462-2920.2012.02810. x.

Sayem S.A., Manzo E., Ciavatta L., Tramice A., Cordone A., Zanfardino A., et al. (2011). Anti-biofilm activity of an exopolysaccharide from a sponge-associated strain of *Bacillus licheniformis*. *Microb Cell Fact*. 27(10): 74. doi:10.1186/1475-2859-10-74.

Yaniv K, Golberg K, Kramarsky-Winter E, Marks R, Pushkarev A, Béjà O, Kushmaro A. (2017). Functional marine metagenomic screening for anti-quorum sensing and anti-biofilm activity. *Biofouling* 33(1): 1–13. doi: 10.1080/08927014.2016.1253684

You J, Xue X, Cao L, Lu X, Wang J, Zhang L, Zhou S.V. (2007). Inhibition of Vibrio biofilm formation by a marine actinomycete strain A66. *Appl Microbiol Biotechnol.* 76 (5):1137–1144.

CHAPTER 7

BENEFITS AND DAMAGES OF LACTIC ACID BACTERIA BIOFILM IN THE FOOD INDUSTRY

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INTRODUCTION

Lactic acid bacteria (LAB) are bacteria that are within the phylum of Firmicutes, Gram-positive, rod or cocci-shaped, facultatively anaerobic, low G+C%, catalase-negative, non-motile (except for a few privileged members), lack cytochrome, do not form spores (except *Sporolactobacillus inulinus*), and generate lactic acid as the end-product during carbohydrate fermentation. The main LAB genera are *Lactobacillus, Lactococcus, Leuconostoc, Pediococcus, Oenococcus, Enterococcus,* and *Streptococcus* (Gómez et al., 2016; Arena et al., 2017). LAB is isolated from different sources such as milk, meat, wine, soil, silages, bread, sauerkraut, and sausages as food-related habitats (Arena et al., 2017; Mgomi et al., 2023).

LABs are usually recognized as safe (GRAS) and, therefore, recognized as food-grade bacteria. Thus, from a legal perspective, they can easily be used in foods as probiotics (Abid et al., 2018). Furthermore, LABs serve as starter cultures in the fermentation of various foods and often help modify and preserve flavor and texture. *Lactobacillus, Pediococcus, Oenococcus, Lactococcus, Leuconostoc,* and *Streptococcus* are important genera for food biotechnology (Rothstein et al., 2020). Most LAB transform lactose and other sugars into lactic acid (Aoudia et al., 2016). Lactic acid limits the growth of food spoilage microorganisms, lowers the pH of the food substrate, and provides foods with a characteristic sour taste

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REFERENCE

Abdel-Nasser, A., Hathout, A. S., Badr, A. N., Barakat, O. S., & Fathy, H. M. (2023). Extraction and characterization of bioactive secondary metabolites from lactic acid bacteria and evaluating their antifungal and antiaflatoxigenic activity. *Biotechnology Reports*, *38*, e00799.

Abid, Y., Casillo, A., Gharsallah, H., Joulak, I., Lanzetta, R., Corsaro, M. M., ... & Azabou, S. (2018). Production and structural characterization of exopolysaccharides from newly isolated probiotic lactic acid bacteria. *International Journal of Biological Macromolecules*, *108*, 719-728.

Aman, M., Aneeqha, N., Bristi, K., Deeksha, J., Afza, N., Sindhuja, V., & Shastry, R. P. (2021). Lactic acid bacteria inhibits quorum sensing and biofilm formation of *Pseudomonas aeruginosa* strain JUPG01 isolated from rancid butter. *Biocatalysis and Agricultural Biotechnology*, *36*, 102115.

Amel, A. M., Farida, B., & Djamila, S. (2015). Anti-adherence potential of *Enterococcus durans* cells and its cell-free supernatant on plastic and stainless steel against foodborne pathogens. *Folia Microbiologica*, *60*, 357-363.

Andreevskaya, M., Johansson, P., Laine, P., Smolander, O. P., Sonck, M., Rahkila, R., ... & Björkroth, J. (2015). Genome sequence and transcriptome analysis of meat-spoilage-associated lactic acid bacterium *Lactococcus piscium* MKFS47. *Applied and Environmental Microbiology*, *81*(11), 3800-3811.

Aoudia, N., Rieu, A., Briandet, R., Deschamps, J., Chluba, J., Jego, G., ... & Guzzo, J. (2016). Biofilms of *Lactobacillus plantarum* and *Lactobacillus fermentum*: Effect on stress responses, antagonistic effects on pathogen growth and immunomodulatory properties. *Food Microbiology*, *53*, 51-59.

Arena, M. P., Capozzi, V., Spano, G., & Fiocco, D. (2017). The potential of lactic acid bacteria to colonize biotic and abiotic surfaces and the investigation of their interactions and mechanisms. *Applied Microbiology and Biotechnology*, *101*, 2641-2657.

Arqués, J. L., Rodríguez, E., Nuñez, M., & Medina, M. (2011). Combined effect of reuterin and lactic acid bacteria bacteriocins on the inactivation of food-borne pathogens in milk. *Food Control*, *22*(3-4), 457-461.

Bajrami, D., Fischer, S., Barth, H., Sarquis, M. A., Ladero, V. M., Fernández, M., ... & Mizaikoff, B. (2022). In situ monitoring of *Lentilactobacillus parabuchneri* biofilm formation via real-time infrared spectroscopy. *npj Biofilms and Microbiomes*, *8*(1), 92.

Brooks, J. D., & Flint, S. H. (2008). Biofilms in the food industry: problems and potential solutions. *International Journal of Food Science & Technology*, *43*(12), 2163-2176.

Camargo, A. C., Todorov, S. D., Chihib, N. E., Drider, D., & Nero, L. A. (2018). Lactic acid bacteria (LAB) and their bacteriocins as alternative biotechnological tools to control *Listeria monocytogenes* biofilms in food processing facilities. *Molecular Biotechnology*, *60*, 712-726.

Castellano, P., Pérez Ibarreche, M., Blanco Massani, M., Fontana, C., & Vignolo, G. M. (2017). Strategies for pathogen biocontrol using lactic acid bacteria and their metabolites: A focus on meat ecosystems and industrial environments. *Microorganisms*, *5*(3), 38.

Chmielewski, R. A. N., & Frank, J. F. (2003). Biofilm formation and control in food processing facilities. *Comprehensive Reviews in Food Science and Food Safety*, *2*(1), 22-32.

De, S., Malik, S., Ghosh, A., Saha, R., & Saha, B. (2015). A review on natural surfactants. *RSC Advances*, *5*(81), 65757-65767.

Dellias, M. D. T. F., Borges, C. D., Lopes, M. L., da Cruz, S. H., de Amorim, H. V., & Tsai, S. M. (2018). Biofilm formation and antimicrobial sensitivity of lactobacilli contaminants from sugarcane-based fuel ethanol fermentation. *Antonie Van Leeuwenhoek*, *111*, 1631-1644.

Fan, Y., Huang, X., Chen, J., & Han, B. (2020). Formation of a mixed-species biofilm is a survival strategy for unculturable lactic acid bacteria and *Saccharomyces cerevisiae* in Daqu, a Chinese traditional fermentation starter. *Frontiers in Microbiology*, *11*, 138.

Gandhi, M., & Chikindas, M. L. (2007). *Listeria*: a foodborne pathogen that knows how to survive. *International Journal of Food Microbiology*, *113*(1), 1-15.

Gómez, N. C., Ramiro, J. M., Quecan, B. X., & de Melo Franco, B. D. (2016). Use of potential probiotic lactic acid bacteria (LAB) biofilms for the control of *Listeria monocytogenes, Salmonella* Typhimurium, and *Escherichia coli* O157: H7 biofilms formation. *Frontiers in Microbiology*, 863.

Gram, L., Ravn, L., Rasch, M., Bruhn, J. B., Christensen, A. B., & Givskov, M. (2002). Food spoilage—interactions between food spoilage bacteria. *International Journal of Food Microbiology*, *78*(1-2), 79-97.

Gu, Y., Tian, J., Zhang, Y., Wu, R., Li, L., Zhang, B., & He, Y. (2021). Dissecting signal molecule AI-2 mediated biofilm formation and environmental tolerance in *Lactobacillus plantarum*. *Journal of Bioscience and Bioengineering*, *131*(2), 153-160.

Guerrieri, E., de Niederhäusern, S., Messi, P., Sabia, C., Iseppi, R., Anacarso, I., & Bondi, M. (2009). Use of lactic acid bacteria (LAB) biofilms for the control of *Listeria monocytogenes* in a small-scale model. *Food Control*, *20*(9), 861-865.

Hladíková, Z., Smetanková, J., Greif, G., & Greifová, M. (2012). Antimicrobial activity of selected lactic acid cocci and production of organic acids. *Acta Chimica Slovaca*, *5*(1), 80-85.

Johansson, P., Paulin, L., Säde, E., Salovuori, N., Alatalo, E. R., Björkroth, K. J., & Auvinen, P. (2011). Genome sequence of a food spoilage lactic acid bacterium, *Leuconostoc gasicomitatum* LMG 18811T, in association with specific spoilage reactions. *Applied and Environmental Microbiology*, *77*(13), 4344-4351.

Kaur, S., Kaur, P., & Nagpal, R. (2015). In vitro biosurfactant production and biofilm inhibition by lactic acid bacteria isolated from fermented food products. *International Journal of Probiotics & Prebiotics*, *10*(1), 17.

Kiew, T. Y., Cheow, W. S., & Hadinoto, K. (2014). Importance of biofilm age and growth medium on the viability of probiotic capsules containing *Lactobacillus rhamnosus* GG biofilm. *LWT-Food Science and Technology*, *59*(2), 956-963.

Kilic, T., & Bali, E. B. (2023). Biofilm control strategies in the light of biofilm-forming microorganisms. *World Journal of Microbiology and Biotechnology*, *39*(5), 131.

Kubota, H., Senda, S., Nomura, N., Tokuda, H., & Uchiyama, H. (2008). Biofilm formation by lactic acid bacteria and resistance to environmental stress. *Journal of Bioscience and Bioengineering*, *106*(4), 381-386.

Kumar, C. G., & Anand, S. K. (1998). Significance of microbial biofilms in food industry: a review. *International Journal of Food Microbiology*, *42*(1-2), 9-27.

Lyhs, U., Korkeala, H., Vandamme, P., & Björkroth, J. (2001). *Lactobacillus alimentarius*: a specific spoilage organism in marinated herring. *International Journal of Food Microbiology*, *64*(3), 355-360.

Mao, Y., Wang, Y., Luo, X., Chen, X., & Wang, G. (2023). Impact of cell-free supernatant of lactic acid bacteria on *Staphylococcus aureus* biofilm and its metabolites. *Frontiers in Veterinary Science*, *10*, 1184989.

Mgomi, F. C., Yang, Y. R., Cheng, G., & Yang, Z. Q. (2023). Lactic acid bacteria biofilms and their antimicrobial potential against pathogenic microorganisms. *Biofilm*, 100118.

Moradi, M., Kousheh, S. A., Almasi, H., Alizadeh, A., Guimarães, J. T., Yılmaz, N., & Lotfi, A. (2020). Postbiotics produced by lactic acid bacteria: The next frontier in food safety. *Comprehensive Reviews in Food Science and Food Safety*, *19*(6), 3390-3415.

Ndahetuye, J. B., Koo, O. K., O'Bryan, C. A., Ricke, S. C., & Crandall, P. G. (2012). Role of lactic acid bacteria as a biosanitizer to prevent attachment of *Listeria monocytogenes* F6900 on deli slicer contact surfaces. *Journal of Food Protection*, *75*(8), 1429-1436.

Pang, X., Song, X., Chen, M., Tian, S., Lu, Z., Sun, J., ... & Yuk, H. G. (2022). Combating biofilms of foodborne pathogens with bacteriocins by lactic acid bacteria in the food industry. *Comprehensive Reviews in Food Science and Food Safety*, *21*(2), 1657-1676.

Piard, J. C., & Briandet, R. (2015). Lactic acid bacteria biofilms: from their formation to their health and biotechnological potential. *Biotechnology of Lactic Acid Bacteria: Novel Applications*, 341-361.

Pothakos, V., Devlieghere, F., Villani, F., Björkroth, J., & Ercolini, D. (2015). Lactic acid bacteria and their controversial role in fresh meat spoilage. *Meat Science*, *109*, 66-74.

Poulsen, L. V. (1999). Microbial biofilm in food processing. *LWT-Food Science and Technology*, *32*(6), 321-326.

Ramírez, M. D. F., Smid, E. J., Abee, T., & Groot, M. N. N. (2015). Characterisation of biofilms formed by *Lactobacillus plantarum* WCFS1 and food spoilage isolates. *International Journal of Food Microbiology*, *207*, 23-29.

Reda, F. M. (2019). Antibacterial and anti-adhesive efficiency of *Pediococcus acidilactici* against fo-

odborne biofilm producer *Bacillus cereus* attached on different food processing surfaces. *Food Science and Biotechnology*, *28*(3), 841-850.
Reis, J. A., Paula, A. T., Casarotti, S. N., & Penna, A. L. B. (2012). Lactic acid bacteria antimicrobial compounds: characteristics and applications. *Food Engineering Reviews*, *4*, 124-140.
Riedl, R., Goderbauer, P., Brandl, A., Jacob, F., & Hutzler, M. (2017). Bavarian wheat beer, an example of a special microbe habitat–cultivation, detection, biofilm formation, characterization of selected lactic acid bacteria hygiene indicators and spoilers. *Brewing Science*, *70*(February), 39-50.
Rodríguez-Saavedra, M., de Llano, D. G., & Moreno-Arribas, M. V. (2020). Beer spoilage lactic acid bacteria from craft brewery microbiota: Microbiological quality and food safety. *Food Research International*, *138*, 109762.
Rothstein, S. M., Sen, S., & Mansell, T. J. (2020). Towards high-throughput genome engineering in lactic acid bacteria. *Current Opinion in Biotechnology*, *61*, 181-188.
Siedler, S., Balti, R., & Neves, A. R. (2019). Bioprotective mechanisms of lactic acid bacteria against fungal spoilage of food. *Current Opinion in Biotechnology*, *56*, 138-146.
Somers, E. B., Johnson, M. E., & Wong, A. C. L. (2001). Biofilm formation and contamination of cheese by nonstarter lactic acid bacteria in the dairy environment. *Journal of Dairy Science*, *84*(9), 1926-1936.
Vallejo, C. M., Restrepo, M. A. F., Duque, F. L. G., & Díaz, J. C. Q. (2021). Production, characterization and kinetic model of biosurfactant produced by lactic acid bacteria. *Electronic Journal of Biotechnology*, *53*, 14-22.
Wong, H. C., & Chen, Y. L. (1988). Effects of lactic acid bacteria and organic acids on growth and germination of *Bacillus cereus*. *Applied and Environmental Microbiology*, *54*(9), 2179-2184.
Zapaśnik, A., Sokołowska, B., & Bryła, M. (2022). Role of lactic acid bacteria in food preservation and safety. *Foods*, *11*(9), 1283.
Zhang, Y., Gu, Y., Wu, R., Zheng, Y., Wang, Y., Nie, L., ... & He, Y. (2022). Exploring the relationship between the signal molecule AI-2 and the biofilm formation of *Lactobacillus sanfranciscensis*. *LWT*, *154*, 112704.

CHAPTER 8

SOME MERISTIC AND MORPHOMETRIC CHARACTERISTICS OF *Arabibarbus grypus* (Heckel, 1843) LIVING IN KARAKAYA DAM LAKE

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INTRODUCTION

The body of *Arabibarbus grypus* is from the Cyprinidae family, is flattened on the sides and covered with large scales. The body is seen as round from the front of the dorsal fin. Next to the large fleshy lips, the mouth is located ventrally. The dorsal fin is further forward than the ventral fin. The abdominal areas are dirty yellow, the sides tend to dark brown, and the back is dark brown. Sometimes there are greenish reflections on the sides of the fish's body. The fins except the caudal and anal fins are light colored and these are dark colored. Its distribution areas are the Euphrates and Tigris river systems (Geldiay & Balık, 2007; Düşükcan, Çalta & Eroğlu, 2015; Düşükcan & Çalta, 2018; Yüksel, Demirol, Gündüz & Çoban, 2020).

Within the scope of biological characteristics of fish, determining their morphometric and meristic properties in different water systems is important for ichthyofauna. In order to reveal the ichthyofauna in a wetland, the biological characteristics of all fish species must known and periodic monitoring studies must carried out. Determining the morphometric and meristic properties of fish in different water systems within the scope of their biological characteristics will important for ichthyofauna. Studies on fish populations should evaluated from

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REFERENCES

Avşar, D. (1998). Balıkçılık biyolojisi ve populasyon dinamiği. Ders Kitabı No: 5. Baki Kitap ve Yayınevi. Adana. 303s.

Bayhan, Y. K. (2021). The Fish Fauna of the Atatürk Dam Lake (Adıyaman/Turkey). NESciences, 6(3): 237-255 doi: 10.28978/nesciences.1036854

Bulut, H., & Saler, S. (2016a). Monthly Varıatıons of Zooplankton In A Freshwaterbody Maryap Pond Turkey. Academic Journal of Science, *6*(1), 39–52.

Bulut, H., & Saler, S. (2016b). Assessment of zooplankton by the index analysis in Kaldırım and Halikan Ponds Malatya Turkey. Biological Diversity and Conser*vation*, *9*(3), 70–77.

Bulut, H., & Saler, S. (2020). Monthly Distribution Of Zooplankton İn Kapikaya Reservoir Turkey. Maejo Internationaljournal of Science And Technology, 14 (01), 1-10.

Düşükcan, M., Çalta, M., & Eroğlu, M. (2015). Keban Baraj Gölü'nde Yaşayan *Barbus grypus* Heckel, 1843'de Otolit Biyometrisi-Balık Boyu İlişkisi (Elazığ, Türkiye). Aquaculture Studies, 15(3), 21-29. DOI: 10.17693/yunusae.v15i21957.235772

Düşükcan, M., & Çalta, M. (2018). Karakaya Baraj Gölü'nden Yakalanan *Barbus grypus* Heckel, 1843 Balık Türünde Toplam Boy-Otolit Biyometrisi İlişkisi. Süleyman Demirel Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 22, 58-64.

Düşükcan, M., Eroğlu, M., & Çoban, M. Z. (2022). Özlüce Baraj Gölü (Elazığ-Bingöl, Türkiye)'nde yaşayan *Alburnus sellal* Heckel, 1843 populasyonunda bazı morfometrik ve meristik özelliklerinin incelenmesi. Acta Aquatica Turcica, 18(4), 486-494. https://doi.org/10.22392/actaquatr.1117235

Geldiay, R., & Balık, S. (2007). Türkiye tatlı su balıkları. Ege Üniversitesi Su Ürünleri Fakültesi Yayınları No: 46, V. Baskı, İzmir, 638s

Gül, G., Yılmaz, M., Saylar, Ö., Benzer, S., & Gül, A. (2017). Mogan Gölü (Ankara, Türkiye) Sazan (*Cyprinus carpio*) Populasyonunun Morfometrik, Meristik Özellikleri ve Boy-Ağırlık İlişkisi. Süleyman Demirel Üniversitesi Eğirdir Su Ürünleri Fakültesi Dergisi, 13(2), 163-172.

Koyun, M., Gül, B., & Korkut, N. (2018). The Fish Fauna of Göynük Stream (Bingöl). 2 (1): 39-47. DOI: 10.31594/commagene.403367

Kubilay, N. (2021). Fırat-Dicle Havzasında bazı *Alburnus sellal* Heckel, 1843 populasyonlarının geometrik morfometrik analizi [Yüksek lisans tezi, Nevşehir Hacı Bektaş Veli Üniversitesi]

Saler, S., Bulut, H., & Karakaya, G. (2019). Zooplankton Of Çat Dam Lake (Malatya-Turkey) With A New Record For Turkish Rotifers *Lecane intrasinuata* (Olofsson 1917). İranian Journal Of Fisheries Sciences, 18(1), 199–204.

URL-1. (2022). Karakaya Barajı-Google Haritalar. https://www.google.com/maps/place/Karakaya+-Baraj%C4%B1/@38.4958341,38.4187461,67047m/dat=!3m2!1e3!4b1!4m5!3m4!1s0x40765dac226aba2d:0xe42a7263672e73c3!8m2!3d38.4662591!4d38.5 233226.

Vatandoust, S., Abdoli, A., Anvarifar, H., & Hamed Mousavi-Sabet, H.M. (2014). Morphometric and meristic characteristics and morphological differentiation among five populations of brown trout *Salmo trutta fario* (Pisces: Salmonidae) along the southern Caspian Sea Basin. European Journal of Zoological Research, 3(2), 56-65.

Yıldırım T., Şen D., Eroğlu M., Çoban M. Z., Demirol, F., Gündüz F., Arca S., Demir T., Gürçay S., Uslu, A. A., & Canpolat, İ. (2015). Keban Baraj Gölü balık faunası, Elazığ - Türkiye. Fırat Üniversitesi Fen Bilimleri Dergisi 27 (1): 57-69.

Yüksel, F., Demirol, F., Gündüz, F., & Çoban, M.Z. (2020). Estimation of Gillnet Selectivity for Shabbout (*Arabibarbus grypus* Heckel, 1843). Fresenius Environmental Bulletin, 29 (9A), 8675-8681.

CHAPTER 9

THE USE OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN THE BIOLOGICAL SCIENCES

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INTRODUCTION

Artificial Intelligence (AI) is one of the fundamental research areas in computer science. With its rapid technological advancements and broad application scope, artificial intelligence has become widespread very quickly, especially due to its strong applicability in solving problems that are not easily addressed by traditional computing structures, particularly those challenging for humans (Rich and Knight, 2009).

The progress of science and technology has brought about developments in various fields, from unraveling the genetic structures of living organisms to the creation of satellites for geographic information systems. The new knowledge emerging in every aspect of our lives, ranging from natural sciences to social sciences, is processed through the use of mathematical models and computer software, facilitating the refinement of large amounts of data (Eaton et al., 2020). Therefore, in the 21st century where the organization of any acquired information is increasingly crucial, it is evident that mathematics and computerized processes will play a prominent role in understanding scientific data. Particularly, the field of biomathematics (mathematical biology), a subset of applied mathematics, is gaining more attention as it quantitatively evaluates data in biological sciences, which are integral to daily life. Interdisciplinary studies encompassing biology, mathematics, and computer science are becoming more prevalent. To the extent that the applications of biomathematics are becoming inevitable in the career plans of young individuals (Akman et al., 2020).

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tutions towards investing in research and development within this field. Several major tech companies have made strides and introduced new approaches in deep learning, fostering the evolution of new applications and perspectives. Entities such as Google, Microsoft, Baidu, IBM, Apple, Nvidia, Facebook, Twitter, Amazon, among many others, have actively engaged in research and development pertaining to deep learning.

When examining the studies conducted, it becomes evident that deep learning architectures have introduced a new perspective and breakthrough in artificial intelligence technologies. The research on future predictions using deep learning architectures is believed to propel current technologies several years forward. The active integration of deep learning architectures into our lives is noticeably geared towards simplifying human life and facilitating the pursuit of a healthy lifestyle. With a particular focus on biology, the utilization of deep learning architectures is seen as a pivotal driver in advancing predictive capabilities and discoveries. Especially within the realm of biology, the application of deep learning architectures is increasingly playing a more effective role in diagnostics, treatment procedures, and disease prognostication. This is perceived as a significant stride towards enhancing human life quality concerning health-related aspects.

REFERENCES

Aamir, M., Rahman, Z., Dayo, Z. A., Abro, W. A., Uddin, M. I., Khan, I., ... & Hu, Z. (2022). A deep learning approach for brain tumor classification using MRI images. *Computers and Electrical Engineering*, *101*, 108105.

Akman, O., Eaton, C. D., Hrozencik, D. Jenkins, K. P., & Thompson, K. V. (2020). Building community-based approaches to systemic reform in mathematical biology education. *Bulletin of Mathematical Biology*, 82(109). https://doi.org/10.1007/s11538-020-00781-4

Akselrod-Ballin, A., Karlinsky, L., Alpert, S., Hasoul, S., Ben-Ari, R., & Barkan, E. (2016). A region based convolutional network for tumor detection and classification in breast mammography. In Deep Learning and Data Labeling for Medical Applications (pp. 197- 205). Springer, Cham.

Al Rahhal, M. M., Bazi, Y., AlHichri, H., Alajlan, N., Melgani, F., & Yager, R. R. (2016). Deep learning approach for active classification of electrocardiogram signals. Information Sciences, 345, 340-354.

Alexe, B., Deselaers, T., & Ferrari, V. (2012). Measuring the objectness of image windows. IEEE transactions on pattern analysis and machine intelligence, 34(11), 2189-2202

An, X., Kuang, D., Guo, X., Zhao, Y., & He, L. (2014). A deep learning method for classification of EEG data based on motor imagery. In International Conference on Intelligent Computing (pp. 203-210). Springer, Cham.

Asgari, E., & Mofrad, M. R. (2015). Continuous distributed representation of biological sequences for deep proteomics and genomics. PloS one, 10(11), e0141287.

Ayaz, M., Sharma, T., & Rao, S. H. (2023). Disruptive artificial intelligence (AI) use-cases in insurance. In AIP Conference Proceedings (Vol. 2782, No. 1). AIP Publishing.

Baltruschat, I. M., Nickisch, H., Grass, M., Knopp, T., & Saalbach, A. (2018). Comparison of Deep Learning Approaches for Multi-Label Chest X-Ray Classification. arXiv preprint arXiv:1803.02315.

References

Bar-Cohen, Y. (2003). Actuation Of Biologically Inspired Intelligent Robotics Using Artificial Muscles. *Industrial Robot*, 30 (4), 331-337. https://doi.org/10.1108/01439910310479702

Botvinick, M., Ritter, S., Wang, J. X., Kurth-Nelson, Z., Blundell, C., & Hassabis, D. (2019). Reinforcement learning, fast and slow. Trends in cognitive sciences, 23(5), 408-422.

Breiman, L. (2001). Statistical modeling: The two cultures (with comments and a rejoinder by the author). *Statistical science*, *16*(3), 199-231.

Cao, Z., Simon, T., Wei, S. E., & Sheikh, Y. (2017, July). Realtime multi-person 2d pose estimation using part affinity fields. In CVPR (Vol. 1, No. 2, p. 7).

Chen, C. L., Mahjoubfar, A., Tai, L. C., Blaby, I. K., Huang, A., Niazi, K. R., & Jalali, B. (2016). Deep learning in label-free cell classification. Scientific reports, 6, 21471

Cheng, M. M., Zhang, Z., Lin, W. Y., & Torr, P. (2014). BING: Binarized normed gradients for objectness estimation at 300fps. In Proceedings of the IEEE conference on computer vision and pattern recognition (pp. 3286-3293).

Collins, F. S., Green, E. D., Guttmacher, A. E., & Guyer, M. S. (2003). A vision for the future of genomics research. *Nature*, 422(6934), Article 6934. https://doi.org/10.1038/nature01626

Cruz-Roa, A. A., Ovalle, J. E. A., Madabhushi, A., & Osorio, F. A. G. (2013). A deep learning architecture for image representation, visual interpretability and automated basal-cell carcinoma cancer detection. In International Conference on Medical Image Computing and Computer-Assisted Intervention(pp. 403-410). Springer, Berlin, Heidelberg

Cunningham, P., Cord, M., & Delany, S. J. (2008). Supervised learning. In Machine learning techniques for multimedia: case studies on organization and retrieval (pp. 21-49). Berlin, Heidelberg: Springer Berlin Heidelberg.

D'Agostino, N., Bentley, A., & Chen, C. (Eds.). (2023). *Genome wide association studies and genomic selection for crop improvement in the era of big data*. Frontiers Media SA.

Dike, H. U., Zhou, Y., Deveerasetty, K. K., & Wu, Q. (2018, October). Unsupervised learning based on artificial neural network: A review. In 2018 IEEE International Conference on Cyborg and Bionic Systems (CBS) (pp. 322-327). IEEE.

Eaton, C. D., LaMar, M. D., & McCarthyc M. L. (2020). 21st century reform efforts in undergraduate quantitative biology education: Conversations, initiatives, and curriculum change in the United States of America. *Letters in Biomathematics*, 7(1), 55-66

Esteva, A., Kuprel, B., Novoa, R. A., Ko, J., Swetter, S. M., Blau, H. M., & Thrun, S. (2017). Dermatologist-level classification of skin cancer with deep neural networks. Nature, 542(7639), 115.

Fakoor, R., Ladhak, F., Nazi, A., & Huber, M. (2011). Using deep learning to enhance cancer diagnosis and classification. In Proceedings of the International Conference on Machine Learning (Vol. 28).

Fu, H., Xu, Y., Wong, D. W. K., & Liu, J. (2016). Retinal vessel segmentation via deep learning network and fully-connected conditional random fields. In Biomedical Imaging (ISBI), 2016 IEEE 13th International Symposium on (pp. 698-701).

Garabaghi, F. H., Benzer, R., Benzer, S., & Günal, A. Ç. (2022). Effect of polynomial, radial basis, and Pearson VII function kernels in support vector machine algorithm for classification of crayfish. *Ecological Informatics*, *72*, 101911.

Garcia, J., & Fernández, F. (2015). A comprehensive survey on safe reinforcement learning. Journal of Machine Learning Research, 16(1), 1437-1480.

Gaur, L., Bhatia, U., Jhanjhi, N. Z., Muhammad, G., & Masud, M. (2023). Medical image-based detection of COVID-19 using deep convolution neural networks. *Multimedia systems*, *29*(3), 1729-1738.

Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep learning*. MIT press.

Han, M., Wu, H., Chen, Z., Li, M., & Zhang, X. (2023). A survey of multi-label classification based on supervised and semi-supervised learning. *International Journal of Machine Learning and Cybernetics*, 14(3), 697-724.

Hinton, G. E., Osindero, S., & Teh, Y. W. (2006). A fast learning algorithm for deep belief nets. *Neural computation*, 18(7), 1527-1554.

Hua, K. L., Hsu, C. H., Hidayati, S. C., Cheng, W. H., & Chen, Y. J. (2015). Computer-aided classification of lung nodules on computed tomography images via deep learning technique. OncoTargets and therapy, 8.

IBM Artificial Intelligence (IBM-AI). (2023). Featured topics. Available online: https://www.ibm.com/cloud/learn/what-is-artificialintelligence (accessed on 03 December.

Jafari, M. H., Nasr-Esfahani, E., Karimi, N., Soroushmehr, S. M., Samavi, S., & Najarian, K. (2016). Extraction of skin lesions from nondermoscopic images using deep learning. arXiv preprint arXiv:1609.02374.

James, G., Witten, D., Hastie, T., Tibshirani, R., & Taylor, J. (2023). Unsupervised learning. In An Introduction to Statistical Learning: with Applications in Python (pp. 503-556). Cham: Springer International Publishing.

Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245), 255-260.

Khanafer, M., & Shirmohammadi, S. (2020). Applied AI in instrumentation and measurement: The deep learning revolution. *IEEE Instrumentation & Measurement Magazine*, *23*(6), 10-17.

Kussul, N., Lavreniuk, M., Skakun, S., & Shelestov, A. (2017). Deep learning classification of land cover and crop types using remote sensing data. IEEE Geoscience and Remote Sensing Letters, 14(5), 778-782.

Li, Y., Sixou, B., & Peyrin, F. (2021). A review of the deep learning methods for medical images super resolution problems. *Irbm*, *42*(2), 120-133.

Liu, B., & Liu, B. (2011). Supervised learning. Web Data Mining: Exploring Hyperlinks, Contents, and Usage Data, 63-132.

Liu, M., Hu, L., Tang, Y., Wang, C., He, Y., Zeng, C., ... & Huo, W. (2022). A deep learning method for breast cancer classification in the pathology images. *IEEE Journal of Biomedical and Health Informatics*, *26*(10), 5025-5032.

Mariani, M. M., Machado, I., Magrelli, V., & Dwivedi, Y. K. (2023). Artificial intelligence in innovation research: A systematic review, conceptual framework, and future research directions. *Technovation*, 122, 102623.

Mhlanga, D. (2023). Artificial intelligence and machine learning for energy consumption and production in emerging markets: a review. *Energies*, 16(2), 745.

Mittal, S., Srivastava, S., & Jayanth, J. P. (2022). A survey of deep learning techniques for underwater image classification. *IEEE Transactions on Neural Networks and Learning Systems*.

Moein, M. M., Saradar, A., Rahmati, K., Mousavinejad, S. H. G., Bristow, J., Aramali, V., & Karakouzian, M. (2023). Predictive models for concrete properties using machine learning and deep learning approaches: A review. *Journal of Building Engineering*, 63, 105444.

Murugappan, V., & Sabeenian, R. S. (2017). Texture based medical image classification by using multi-scale gabor rotation-invariant local binary pattern (MGRLBP). Cluster Computing, 1-14.

Nasteski, V. (2017). An overview of the supervised machine learning methods. Horizons. b, 4, 51-62.

Ng, J. Y. H., Hausknecht, M., Vijayanarasimhan, S., Vinyals, O., Monga, R., & Toderici, G. (2015). Beyond short snippets: Deep networks for video classification. In Computer Vision and Pattern Recognition (CVPR), 2015 IEEE Conference on (pp. 4694-4702)

Nguyen, A., Clune, J., Bengio, Y., Dosovitskiy, A., & Yosinski, J. (2017). Plug & play generative networks: Conditional iterative generation of images in latent space. In Computer Vision and Pattern Recognition (CVPR), 2017 IEEE Conference on (pp. 3510- 3520)

Nian, R., Liu, J., & Huang, B. (2020). A review on reinforcement learning: Introduction and applications in industrial process control. *Computers & Chemical Engineering*, 139, 106886.

Ong, P., Tan, Y. K., Lai, K. H., & Sia, C. K. (2023). A deep convolutional neural network for vibration-based health-monitoring of rotating machinery. *Decision Analytics Journal*, *7*, 100219.

Patange, G. S., & Pandya, A. B. (2023). How artificial intelligence and machine learning assist in industry 4.0 for mechanical engineers. Materials Today: Proceedings, 72, 622-625.

Pauly, D., & Morgan, G. R. (Eds.). (1987). Length-based methods in fisheries research (Vol. 13). WorldFish.

Pichler, M., & Hartig, F. (2023). Machine learning and deep learning—A review for ecologists. *Methods in Ecology and Evolution*, 14(4), 994-1016.

Piczak, K. J. (2015, September). Environmental sound classification with convolutional neural networks. In Machine Learning for Signal Processing (MLSP), 2015 IEEE 25th International Workshop on (pp. 1-6).

Prudencio, R. F., Maximo, M. R., & Colombini, E. L. (2023). A survey on offline reinforcement learning: Taxonomy, review, and open problems. IEEE Transactions on Neural Networks and Learning Systems.

Rich, E., & Knight, K. (2009). *Artificial intelligence*, Third Edition, Ed. New Delhi: McGraw-Hill,

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fisheries Research Board of Canada*.

Shah, H. M., Gardas, B. B., Narwane, V. S., & Mehta, H. S. (2023). The contemporary state of big data analytics and artificial intelligence towards intelligent supply chain risk management: a comprehensive review. *Kybernetes*, 52(5), 1643-1697.

Sharma, S., & Guleria, K. (2022, April). Deep learning models for image classification: comparison and applications. In *2022 2nd International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE)* (pp. 1733-1738). IEEE.

Shinde, P. P., & Shah, S. (2018, August). A review of machine learning and deep learning applications. In 2018 Fourth International Conference on computing communication control and automation (ICCUBEA) (pp. 1-6). IEEE.

Sirinukunwattana, K., Raza, S. E. A., Tsang, Y. W., Snead, D. R., Cree, I. A., & Rajpoot, N. M. (2016). Locality sensitive deep learning for detection and classification of nuclei in routine colon cancer histology images. IEEE transactions on medical imaging, 35(5), 1196- 1206.

Stelios, S. (2023). *Artificial Intelligence or Artificial Morality. Technology*, Users and Uses: Ethics and Human Interaction through Technology and AI.

Suk, H. I., & Shen, D. (2013). Deep learningbased feature representation for AD/MCI classification. In International Conference on Medical Image Computing and ComputerAssisted Intervention (pp. 583-590). Springer, Berlin, Heidelberg.

Tamilselvan, P., & Wang, P. (2013). Failure diagnosis using deep belief learning based health state classification. Reliability Engineering & System Safety, 115, 124-135.

Tarando, S. R., Fetita, C., Faccinetto, A., & Brillet, P. Y. (2016). Increasing CAD system efficacy for lung texture analysis using a convolutional network. In Medical Imaging 2016: Computer-Aided Diagnosis (Vol. 9785, p. 97850Q). International Society for Optics and Photonics

Tian, C., Fei, L., Zheng, W., Xu, Y., Zuo, W., & Lin, C. W. (2020). Deep learning on image denoising: An overview. *Neural Networks*, *131*, 251-275.

Tulbure, A. A., Tulbure, A. A., & Dulf, E. H. (2022). A review on modern defect detection models using DCNNs–Deep convolutional neural networks. *Journal of Advanced Research*, *35*, 33-48.

Uijlings, J. R., Van De Sande, K. E., Gevers, T., & Smeulders, A. W. (2013). Selective search for object recognition. International journal of computer vision, 104(2), 154-171.

Van Engelen, J. E., & Hoos, H. H. (2020). A survey on semi-supervised learning. *Machine learning*, *109*(2), 373-440.

van Grinsven, M. J., van Ginneken, B., Hoyng, C. B., Theelen, T., & Sánchez, C. I. (2016). Fast convolutional neural network training using selective data sampling: Application to hemorrhage detection in color fundus images. IEEE transactions on medical imaging, 35(5), 1273-1284.

Wang, H., Fu, T., Du, Y., Gao, W., Huang, K., Liu, Z., ... & Zitnik, M. (2023). Scientific discovery in the age of artificial intelligence. *Nature*, 620(7972), 47-60.

Weisstein, A. E. (2011). Building mathematical models and biological insight in an introductory biology course. *Mathematical Modelling of Natural Phenomena*, 6(6), 198-214.

Wu, C., Zhang, R., Kotagiri, R., & Bouvry, P. (2023). Strategic decisions: Survey, taxonomy, and future directions from artificial intelligence perspective. *ACM Computing Surveys*, 55(12), 1-30.

Xi, L., Yun, Z., Liu, H., Wang, R., Huang, X., & Fan, H. (2022). Semi-supervised time series classification model with self-supervised learning. *Engineering Applications of Artificial Intelligence*, *116*, 105331.

Yang, C. T., Kristiani, E., Leong, Y. K., & Chang, J. S. (2023). Big Data and Machine Learning Driven Bioprocessing-Recent trends and critical analysis. *Bioresource Technology*, 128625.

Yang, X., Song, Z., King, I., & Xu, Z. (2022). A survey on deep semi-supervised learning. *IEEE Transactions on Knowledge and Data Engineering*.

Yoo, Y., Tang, L. W., Brosch, T., Li, D. K., Metz, L., Traboulsee, A., & Tam, R. (2016). Deep learning of brain lesion patterns for predicting future disease activity in patients with early symptoms of multiple sclerosis. In Deep Learning and Data Labeling for Medical Applications (pp. 86-94). Springer, Cham

Yue, Y., Cao, L., Lu, D., Hu, Z., Xu, M., Wang, S., ... & Ding, H. (2023). Review and empirical analysis of sparrow search algorithm. *Artificial Intelligence Review*, 1-53.

Zaadnoordijk, L., Besold, T. R., & Cusack, R. (2022). Lessons from infant learning for unsupervised machine learning. *Nature Machine Intelligence*, 4(6), 510-520.

Zhang, Q., Xiao, Y., Dai, W., Suo, J., Wang, C., Shi, J., & Zheng, H. (2016). Deep learning based classification of breast tumors with shear-wave elastography. Ultrasonics, 72, 150-157.

Zhu, X., & Goldberg, A. B. (2022). *Introduction to semi-supervised learning*. Springer Nature.

Zitnick, C. L., & Dollár, P. (2014). Edge boxes: Locating object proposals from edges. In European Conference on Computer Vision (pp. 391-405). Springer, Cham.