

Journal of Research in Pharmacy

e-ISSN: 2630-6344

Founded: 2010

Period: 6 Issues Per Year

Publisher: Marmara University

Search article in the journal



ABOUT

Journal of Research in Pharmacy is the official scientific journal of Marmara University Faculty of Pharmacy. The journal is the continuation of the former "Journal of Pharmacy of University of Marmara" which was published between 1985 and 1997. Since 2010, the journal has been published online bimonthly (January-March-May-July-September-November). It is an open access, peer-reviewed journal devoted to the publication of papers in pharmacy and pharmaceutical sciences. The journal only accepts articles written in English for evaluation. The journal aims at providing a medium for the dissemination of interdisciplinary papers of interest for many different specialists.

Journal of Research in Pharmacy publishes original research papers, review articles and scientific commentaries on all aspects of pharmaceutical sciences depending on their conceptual novelty and scientific quality. The journal welcomes articles in this multidisciplinary field, with a focus on topics relevant for drug action, drug discovery and development, conventional and emerging fields related to pharmaceutical sciences. Articles which cannot be associated with

ARCHIVE

Latest Issues

[2025 - Volume: 29 Issue: 5](#)

[2025 - Volume: 29 Issue: 4](#)

[2025 - Volume: 29 Issue: 3](#)

[2025 - Volume: 29 Issue: 2](#)

EXPLORE

[» Submit a Manuscript](#)

[» Send Reviewer Request](#)

[> Aim & Scope](#)

[> Author Guidelines](#)

[> Ethical Principles and Publication Policy](#)

[> Price Policy](#)

[> Journal Boards](#)

[> Statistics](#)

[> Indexes](#)

[All Issues](#)

[Contact](#)

[Journal History](#)

CURRENT ISSUE

[Feedback](#)

Journal of Research in Pharmacy

Editorial Board

Editor-in-Chief

Hatice Kübra ELÇİOĞLU

Department of Pharmacology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
kubra.elcioglu@marmara.edu.tr

Co-Editors

Levent KABASAKAL

Department of Pharmacology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
lkabasakal@marmara.edu.tr

Esra TATAR

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
etatar@marmara.edu.tr

Ayşe Nur HAZAR YAVUZ

Department of Pharmacology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
ayse.hazar@marmara.edu.tr

Section Editors

Analytical Chemistry & Therapeutic Drug Monitoring

Anil Kumar DWIVEDI

Central Drug Research Institute, Lucknow, India
anilcdri@gmail.com

Anisa ELHAMILI

Department of Medicinal & Pharmaceutical Chemistry, Faculty of Pharmacy, University of Tripoli, Tripoli, Libya
aaelhamili2000@gmail.com

Emirhan NEMUTLU

Department of Analytical Chemistry, Faculty of Pharmacy, Hacettepe University, Ankara, Türkiye
enemutlu@hacettepe.edu.tr

Lorena MEMUSHAJ

Department of Pharmacy, Faculty of Medical Sciences, Aldent University, Tirana, Albania
lorena.memushaj@ual.edu.al

Mehmet GÜMÜŞTAŞ

Department of Forensic Toxicology, Institute of Forensic Sciences, Ankara University, Ankara, Türkiye
mgumustas@hotmail.com

Mohd Younis RATHER

Multidisciplinary Research Unit, Government Medical College Srinagar, Srinagar, India
younis.rather78@gmail.com

Pınar TALAY PINAR

Department of Analytical Chemistry, Faculty of Pharmacy, Yüzüncü Yıl University, Van, Türkiye
ptalay@gmail.com

Biochemistry & Cancer Research

Beyza Ecem ÖZ BEDİR

Department of Medical Biology, Faculty of Medicine, Ankara Yıldırım Beyazıt University, Ankara, Türkiye
beoz@ybu.edu.tr

Débora DUMMER MEIRA

Department of Biological Sciences, Nucleus of Human and Molecular Genetics, Federal University of Espírito Santo, Vitória- Espírito Santo, Brazil
debora.dummer.meira@gmail.com

Derya ÖZSAVCI

Department of Biochemistry, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
derya.ozsavci@marmara.edu.tr

Emine TERZİ

Department of Medical Biology, Faculty of Medicine, Ankara Yıldırım Beyazıt University, Ankara, Türkiye
emineterzi1990@hotmail.com

Gülberk UÇAR

Department of Biochemistry, Faculty of Pharmacy, Hacettepe University, Ankara, Türkiye
gulberk@hacettepe.edu.tr

Haidar A ABDULAMIR

College of Pharmacy, Al-Maaql University, Basra, Iraq
h_al_attar@yahoo.com

Hamide Sena ÖZBAY

Department of Biochemistry, Faculty of Pharmacy, Hacettepe University, Ankara, Türkiye
senaozbay@hacettepe.edu.tr

Işıl YILDIRIM

Pharmacy Services Program, Beykent University, Istanbul, Türkiye
assistant.professor.isil.yildirim@gmail.com

Lokman AYAZ

Department of Biochemistry, Faculty of Pharmacy, Trakya University, Edirne, Türkiye
lokmanayaz@yahoo.com

Lynda BOUREBABA

Department of Experimental Biology, Faculty of Biology and Animal Science, Wrocław University of Environmental and Life Sciences, Wrocław, Poland
lynda.bourebaba@upwr.edu.pl

Nadia M. HAMDY

Department of Biochemistry, Faculty of Pharmacy, Ain Shams University, Cairo, Egypt
nadia_hamdy@pharma.asu.edu.eg

Sahar AL-OKBI

Nutrition and Food Sciences Department, National Research Centre, Cairo, Egypt
s_y_alokbi@hotmail.com

Selma HOUCHI

Laboratory of Applied Biochemistry, Faculty of Natural and Life Sciences, University Ferhat Abbas, Setif, Algeria
houchi.selma@univ-setif.dz

Biotechnology

Ali Demir SEZER

Department of Pharmaceutical Biotechnology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
adsezer@marmara.edu.tr

Ammad Ahmad FAROOQI

Department of Molecular Oncology, Institute of Biomedical and Genetic Engineering (IBGE), Islamabad, Pakistan
farooqiammadahmad@gmail.com

Ceyda EKENTOK ATICI

Department of Pharmaceutical Biotechnology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
ceyda.ekentok@marmara.edu.tr

Fahima DILNAWAZ

School of Engineering and Technology, Centurion University of Technology and Management, Odisha, INDIA
fahimadilhawaz@gmail.com

Murat DOĞAN

Department of Pharmaceutical Biotechnology, Faculty of Pharmacy, Cumhuriyet University, Sivas, Türkiye
mdogan@cumhuriyet.edu.tr

Uğur KARAGÖZ

Department of Pharmaceutical Biotechnology, Faculty of Pharmacy, Trakya University, Edirne, Türkiye
ugurkaragoz@trakya.edu.tr

Clinical and Social Pharmacy & Pharmacoeconomy & Pharmacy Education**Abdikarim Mohammed ABDI**

Department of Clinical Pharmacy, Faculty of Pharmacy, Yeditepe University, Istanbul, Türkiye
abdikarim.abdi@yeditepe.edu.tr

Ahmed Hamza AL-SHAMMARI

Department of Pharmacy, Kut University College, Alkut, Wasit, Iraq
Ahmedhamzamezaal@gmail.com

Betül OKUYAN

Department of Clinical Pharmacy, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
betul.okuyan@marmara.edu.tr

Emre KARA

Department of Clinical Pharmacy, Faculty of Pharmacy, Hacettepe University, Ankara, Türkiye
emrekara@hacettepe.edu.tr

Ermelinda DURMISHI

Director, Higher Education and Scientific Research Policies Department, Ministry of Education and Sports, Tirana, Albania
eridurmishi@yahoo.com

Maja ORTNER HADŽIABDIĆ

Centre for Applied Pharmacy, Faculty of Pharmacy and Biochemistry, University of Zagreb, Zagreb, Croatia
mortner@pharma.hr

Mesut SANCAR

Department of Clinical Pharmacy, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye
mesut.sancar@marmara.edu.tr

Mirela MIRAÇI

Faculty of Pharmacy, University of Medicine, Tirana, Albania
mirela.miraci@umed.edu.al

Nasir IDKAIDEK

Department of Pharmaceutics and Pharmaceutical Technology, Faculty of Pharmacy and Medical Sciences, Petra University, Amman, Jordan
nidkaidek@uop.edu.jo

Tarik CATIĆ

Department of Pharmacy, Sarajevo School of Science and Technology, Sarajevo, Bosnia and Herzegovina
tarik.catic@ssst.edu.ba

Z.Kübra ÖZDEN YILMAZ

Department of Clinical Pharmacy, Faculty of Pharmacy, Acibadem Mehmet Ali Aydınlar University, Istanbul, Türkiye
zekiye.yilmaz@acibadem.edu.tr

General Chemistry

Sinem GÖKTÜRK

Department of Basic Pharmaceutical Sciences, Faculty of Pharmacy, Marmara University, İstanbul, Türkiye

sgokturk@marmara.edu.tr

In Silico Studies

Berna DOĞAN

Department of Chemistry, Faculty of Science and Letters, Istanbul Technical University, İstanbul, Türkiye

bernadogan@itu.edu.tr

Gizem TATAR YILMAZ

Department of Biostatistics and Medical Informatics, Faculty of Medicine, Karadeniz Technical University, Trabzon, Türkiye

gizemtatar@gmail.com

Onur SERÇİNOĞLU

Department of Bioengineering, Faculty of Engineering, Gebze Technical University, Kocaeli, Türkiye

osercinoglu@gtu.edu.tr

Mehmet ÖZBİL

Department of Bioengineering, Faculty of Engineering, Gebze Technical University, Kocaeli, Türkiye

mozbil@gtu.edu.tr

Medicinal Chemistry

Bahadır BÜLBÜL

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Düzce University, Düzce, Türkiye

bahadir.bulbul@yahoo.com.tr

Efe Doğukan DİNCEL

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Istanbul University, İstanbul, Türkiye

efe.dincel@istanbul.edu.tr

Entela HALOCI

Faculty of Pharmacy, University of Medicine, Tirana, Albania

entela.haloci@umed.edu.al

Göknil Pelin COŞKUN

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Acıbadem University, İstanbul, Türkiye

pelin.coskun@acibadem.edu.tr

Hasan Erdiç SELLİTEPE

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Karadeniz Technical University, Trabzon, Türkiye

esellitepe@ktu.edu.tr

Kerem BURAN

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, University of Health Sciences, İstanbul, Türkiye

Kerem.buran@sbu.edu.tr

Simone CARRADORI

Department of Pharmacy, "G. d'Annunzio" University of Chieti-Pescara, Chieti, Italy

simone.carradori@unich.it

Somaieh SOLTANI

Faculty of Pharmacy, Tabriz University of Medical Sciences, Tabriz, Iran

soltanis@tbzmed.ac.ir

Microbiology & Immunology

Shahram KHADEM VATAN

Department of Medical Parasitology and Mycology, Urmia University of Medical Sciences, Urmia, Iran

Cellular and Molecular Research Center, Cellular and Molecular Medicine Research Institute, Urmia University of Medical Sciences, Urmia, Iran

Khademvatan@yahoo.com

Demet ERDÖNMEZ

Department of Pharmaceutical Microbiology, Faculty of Pharmacy, Düzce University, Düzce, Türkiye

demet.erdonmez@gmail.com

Erkan RAYAMAN

Department of Pharmaceutical Microbiology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

erayaman@marmara.edu.tr

Gülgün TINAZ

Department of Basic Pharmaceutical Sciences, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

gulgun.tinaz@marmara.edu.tr

Zahraa AMER HASHIM

Department of Microbiology and Immunology, College of Pharmacy, Mosul University, Mosul, Iraq

hashimz@uomosul.edu.iq

Pharmaceutical Botany & Pharmacognosy & Chemistry of Natural Products**Ahmet EMİR**

Department of Pharmacognosy, Faculty of Pharmacy, Ege University, Izmir, Türkiye

ahmet.emir@ege.edu.tr

Annalisa CHIAVAROLI

Department of Pharmacology, Faculty of Pharmacy, G. d'Annunzio University of Chieti-Pescara, Chieti, Italy

annalisa.chiavaroli@unich.it

Antoaneta TRENDAFILOVA

Institute of Organic Chemistry with Centre of Phytochemistry, Bulgarian Academy of Sciences, Sofia, Bulgaria

antoaneta.trendafilova@orgchm.bas.bg

Ceren EMİR

Department of Pharmacognosy, Faculty of Pharmacy, Ege University, Izmir, Türkiye

ceren.acir@ege.edu.tr

Claudio FERRANTE

Department of Pharmacology, Faculty of Pharmacy, G. d'Annunzio University of Chieti-Pescara, Chieti, Italy

claudio.ferrante@unich.it

İlker DEMİRBOLAT

Department of Pharmaceutical Chemistry, Faculty of Pharmacy, Acıbadem University, Istanbul, Türkiye

ilker.demirbolat@acibadem.edu.tr

İ. İrem TATLI ÇANKAYA

Department of Pharmaceutical Botany, Faculty of Pharmacy, Hacettepe University, Ankara, Türkiye

iremchankaya@gmail.com

Laleh KHODAIE

Department of Pharmacognosy, Faculty of Traditional Medicine, Tabriz University of Medical Sciences, Tabriz, Iran

khodaiei@gmail.com

Lejla KLEPO

Department of Chemistry, Faculty of Science, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

klepolejla@gmail.com

Mirjana MARČETIĆ

Department of Pharmacognosy, Faculty of Pharmacy, University of Belgrade, Belgrade, Serbia

mirjana.marctic@pharmacy.bg.ac.rs

Nurettin YAYLI

Department of Pharmacognosy, Faculty of Pharmacy, Karadeniz Technical University, Trabzon, Türkiye

yayli@ktu.edu.tr

Patrícia RIJO

Research Center for Biosciences & Health Technologies, Lusofona University, Lisbon, Portugal

pl609@ulusofona.pt

Pharmacognosy

Sneha AGRAWAL

Department of Pharmacognosy, Bharati Vidyapeeth's College of Pharmacy, Navi Mumbai, Maharashtra, India

sneha.agrawal@bvcop.in

Turgut TAŞKIN

Department of Pharmacognosy, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

turguttaskin@marmara.edu.tr

Viktorija MAKSIMOVA

Department of Applied Sciences, Faculty of Medical Sciences, Goce Delcev University, Shtip, Republic of N. Macedonia

viktorija.maksimova@ugd.edu.mk

Vildan ÇELİKSOY

School of Optometry and Vision Sciences, Cardiff University, Cardiff, UK

celiksoyv92@gmail.com

Vilma TOSKA PAPAJANI

Department of Pharmacy, University of Medicine, Tirana, Albania

toskavilma@gmail.com

Zoran ZEKOVIĆ

Faculty of Technology, University of Novi Sad, Novi Sad, Serbia

zzekovic@tf.uns.ac.rs

Pharmaceutics

Monika DWIVEDI

Department of Pharmaceutical Sciences and Technology, Birla Institute of Technology, Mesra, India

monika.nbri@gmail.com

Justė Baranauskaitė ORTASÖZ

Department of Pharmaceutical Technology, Faculty of Pharmacy at Yeditepe University, Istanbul, Türkiye

Department of Analytical and Toxicological Chemistry, Faculty of Pharmacy, Medical Academy, at the Lithuanian University of Health Sciences, Kaunas, Lithuania

juste.ortasoz@yeditepe.edu.tr

juste.baranauskaite@lsmuni.lt

Afife Büşra UĞUR KAPLAN

Department of Pharmaceutical Technology, Faculty of Pharmacy, Atatürk University, Erzurum, Türkiye

afife.busra.ugur@gmail.com

Rajanikant PATEL

Granules Pharmaceuticals Inc., Chantilly, VA - 20151, USA

rajnipharmacy@gmail.com

Burcu ÜNER

Pharmaceutical and Administrative Sciences, The University of Health Science and Pharmacy in St. Louis, USA

uner.burcu@yahoo.com

Dhanashree P. SANAP

Department of Pharmaceutics, Bharati Vidyapeeth's College of Pharmacy, Navi Mumbai, India

dhanashree.sanap@bvcop.in

Dinesh KUMAR

Department of Pharmaceutical Engineering & Technology, Indian Institute of Technology (BHU), Varanasi, India

dinesh.phe@itbhu.ac.in

Ebru ALTUNTAŞ

Department of Pharmaceutical Technology, Faculty of Pharmacy, Istanbul University, Istanbul, Türkiye

ebru.altuntas@istanbul.edu.tr

Ela HOTI

Faculty of Pharmacy, University of Medicine, Tirana, Albania

ela.hoti@umed.edu.al

Emrah ÖZAKAR

Department of Pharmaceutical Technology, Faculty of Pharmacy, Atatürk University, Erzurum, Türkiye

emrahozakar@atauni.edu.tr

Enkelejda GOCI

Pharmacotherapeutic Research Center, Aldent University, Tirana, Albania

enkelejda.goci@ual.edu.al

Kleva SHPATI

Department of Pharmacy, Albanian University, Tirana, Albania

k.shpati@albanianuniversity.edu.al

Sakine TUNCAY TANRIVERDİ

Department of Pharmaceutical Technology, Faculty of Pharmacy, Ege University, İzmir, Türkiye

sakine.tuncay@ege.edu.tr

Gülşah GEDİK

Department of Pharmaceutical Technology, Faculty of Pharmacy, Trakya University, Edirne, Türkiye

gulsahgedik@trakya.edu.tr

Ongun Mehmet SAKA

Department of Pharmaceutical Technology and Biotechnology, Faculty of Pharmacy, Ankara University, Ankara, Türkiye

omsaka@gmail.com

Oya KERİMOĞLU

Department of Pharmaceutical Technology, Faculty of Pharmacy, Marmara University, İstanbul, Türkiye

osipahigil@marmara.edu.tr

Pankaj DWIVEDI

Pharmaceutical and Administrative Sciences, The University of Health Science and Pharmacy in St. Louis, USA

dwivedipank@gmail.com

Rezarta SHKRELI

Department of Pharmacy, Faculty of Medical Sciences, Aldent University, Tirana, Albania

rezarta.shkreli@ual.edu.al

Renuka KHATIK

Washington University in St. Louis, USA

renukadops@gmail.com

Rukiye SEVİNÇ ÖZAKAR

Department of Pharmaceutical Technology, Faculty of Pharmacy, Atatürk University, Erzurum, Türkiye

rukiyeso@atauni.edu.tr

Saeideh SOLTANI

Novel Drug Research Center, School of Pharmacy and Pharmaceutical Sciences, Isfahan University of Medical Sciences, Isfahan, Iran

soltanisa@pharm.mui.ac.ir

Pharmacology & Toxicology**Ana V. PEJČIĆ**

Department of Pharmacology and Toxicology, Faculty of Medical Sciences, University of Kragujevac, Kragujevac, Serbia

anapejcic201502@yahoo.com

Ayfer BECEREN

Department of Pharmaceutical Toxicology, Faculty of Pharmacy, Marmara University, İstanbul, Türkiye

ayfer.tozan@marmara.edu.tr

Ayşe Nur HAZAR YAVUZ

Department of Pharmacology, Faculty of Pharmacy, Marmara University, İstanbul, Türkiye

ayse.hazar@marmara.edu.tr

Ayşenur GÜNAYDIN AKYILDIZ

Department of Pharmaceutical Toxicology, Faculty of Pharmacy, Bezmialem Vakıf University, İstanbul, Türkiye
gunaydinaysenur@gmail.com

Ayça TOPRAK SEMİZ

Vocational School of Health Services, Giresun University, Giresun, Türkiye
ayca.toprak@giresun.edu.tr

Büşra ERTAŞ

Department of Pharmacology, Faculty of Pharmacy, Marmara University, İstanbul, Türkiye
busra.ertas@marmara.edu.tr

Vasudevan MANI

Department of Pharmacology and Toxicology, College of Pharmacy, Qassim University, Al Qassim, Kingdom of Saudi Arabia
v.samy@qu.edu.sa

Fatiha MISSOUN

Laboratory of Pharmacognosy and Api-Phytotherapy, University of Mostaganem, Mostaganem, Algeria
fatiha.missoun@univ-mosta.dz

Klodiola DHAMO

Faculty of Technical Medical Sciences, Aldent University, Tiranë, Albania
klodiola.dhamo@ual.edu.al

Long Chiau MING

School of Medical and Life Sciences, Sunway University, Sunway City, Malaysia
longchiauming@gmail.com

Merve KABASAKAL

Department of Medical Pharmacology, Faculty of Medicine, University of Health Sciences, İstanbul, Türkiye
merve.kabasakal@sbu.edu.tr

Miloš N. MILOSAVLJEVIĆ

Department of Pharmacology and Toxicology, Faculty of Medical Sciences, University of Kragujevac, Kragujevac, Serbia
milosavljevicmilos91@gmail.com

Mohammed Jabbar MANNA

Department of Pharmacology, College of Dentistry, Al-Mustansiriya University, Baghdad, Iraq
mohammedalmanna@uomustansiriyah.edu.iq

Nurdan TEKİN

Department of Medical Pharmacology, Faculty of Medicine, University of Health Sciences, İstanbul, Türkiye
nurdan.tekin@sbu.edu.tr

Oğuzhan AYDEMİR

Department of Pharmacology, Faculty of Pharmacy, İstanbul Kent University, İstanbul, Türkiye
aydemir.oguzhan@hotmail.com

Rümeysa KELEŞ KAYA

Department of Medical Pharmacology, Faculty of Medicine, Sakarya University, Sakarya, Türkiye
rumeysakeles@sakarya.edu.tr

Sana REHMAN

Department of Pharmacology, HIMSR & HAH Hospital, Jamia Hamdard, New Delhi, INDIA
drsanarehman2012@gmail.com

Sinan SERMET

Istinye University Faculty of Medicine, Department of Clinical Sciences and Department of Pharmacology and Clinical Pharmacology, İstanbul, Türkiye
sinan.sermet@istinye.edu.tr

Ünzile YAMAN

Department of Pharmaceutical Toxicology, Faculty of Pharmacy, Katip Çelebi University, İzmir, Türkiye
unzileyaman@gmail.com

Zarife Nigar ÖZDEMİR KUMRAL

Department of Physiology, Faculty of Medicine, Marmara University, Istanbul, Türkiye

znozdemir@marmara.edu.tr

Zeina ALTHANOON

Department of Pharmacology and Toxicology, College of Pharmacy, Mosul University, Mosul, Iraq

dr.zeina@uomosul.edu.iq

Copy Editors**Beyza Nur TOPAL**

Department of Analytical Chemistry, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

beyza.topal@marmara.edu.tr

Damla DAMAR ÇELİK

Department of Pharmaceutical Microbiology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

damla.damar@marmara.edu.tr

Elif Beyzanur POLAT

Department of Pharmacology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

elif.beyzanur@marmara.edu.tr

İşinsu MUTLU

Department of Pharmaceutical Biotechnology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

isinsu.mutlu@marmara.edu.tr

Kadriye ARSLAN

Department of Pharmaceutical Botany, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

kadriye.arslan@marmara.edu.tr

Semanur GÜNER

Department of Pharmacology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

semanur.guner@marmara.edu.tr

Sena ERGÜN

Department of Pharmaceutical Toxicology, Faculty of Pharmacy, Marmara University, Istanbul, Türkiye

sena.ergun@marmara.edu.tr

Language Editor**Khadija ALJESRI**

Department of Pharmacology, Institute of Health Sciences, Marmara University, Istanbul, Türkiye

Biostatistics Editor**Gülnaz NURAL BEKİROĞLU**

Department of Biostatistics, Faculty of Medicine, Marmara University, Istanbul, Türkiye

nural@marmara.edu.tr

Last Update Time: 7/1/25

[Journal Home Page](#)

[About](#)

[Aim & Scope](#)

Volume: 29 Issue: 5, 9/1/25

YEAR: 2025

Articles

Research Article

[1. Development and validation of a UV-Spectrophotometric method using methanol for the simultaneous estimation of doxycycline and voriconazole in pharmaceutical formulations](#)

Dr. Mrs. Neela Bhatia *, Anagha Ajagekar, Rutuja Chougale

Page : 1792-1801

[↓ PDF](#)

Research Article

[2. Anti-inflammatory activity of Stichopus variegatus from Onogate capsule to treat joint pain](#)

Syamsudin Abdillah *, Deni Rahmat, Ema Hermawati, Greesty Finotory Swandiny, Sucipto Kokadir, Edward Basilianus

Page : 1802-1810

[↓ PDF](#)

Research Article

[4. Exploring the anti-cancer potential of Ixora extracts: A multi-cell line approach](#)

Dipanwita Ghoshal, Sangeeta Godbole *

Page : 1823-1834

[↓ PDF](#)

Research Article

[5. Effectiveness and irritability study of glabridin nanoemulsion with oleic acid-EVO oil and oleic acid-palm oil as an oil phase](#)

Putu Devi Febrina Suryandari, Tristiana Erawati *, Noorma Rosita

Page : 1835-1850

[↓ PDF](#)

Research Article

[6. Molecular modelling approaches for the identification of potent sodium-glucose cotransporter 2 inhibitors from Boerhavia diffusa for the potential treatment of chronic kidney disease](#)

Shanmugampillai Jeyarajaguru Kabilan, Oviya Sivakumar, Selvaraj Kunjiappan, Parasuraman Pavada, Krishnan Sundar *

Page : 1851-1877

[↓ PDF](#)

Research Article

[7. Evaluation of hepatoprotective potential of selected schiff bases \(SW8/SB & SW10/SB\) against gentamicin-induced hepatotoxicity](#)

Attaullah Shah *, Shawkat Ali, Haroon Badshah *, Mateen Abbas, Durre Nayab, Wadood Ali Shah

Page : 1878-1889

[↓ PDF](#)

Research Article

[8. The effect of calcium supplements on troponin variables in athletes and their association with bone diseases : Implications for myocardial health](#)

Muntadher Jaber *, Sada Ghalib Taher , Riyadh Rashid Hameed , Sajjad Mohammed Zorah , Doha Jehad Mohammad , Adyan Nafea Abbas ,
Falah Herez Madhloom Alrabea , Samer Kareem Hanoon

Page : 1890-1895

[↓ PDF](#)

Research Article

[9. Understanding the effect of ginger on dental pulp stem cells differentiation into chondrocyte](#)

Payal Pawar , Ajay Kale , Ramesh Bhonde , Pranjali Potdar , Mayuri Chavan , Avinash Kharat *

Page : 1896-1903

[↓ PDF](#)

Research Article

[10. Deciphering the anti-inflammatory pathways: Juniperus macrocarpa's role in IL-6 and TNF modulation in gastric ulcer healing on rats model](#)

Sura Ahmed Al Jabbara *, Mohammed Qasim Yahya Malallah A. Al-atrakji

Page : 1904-1917

[↓ PDF](#)

Research Article

[11. Reworking potential of Cassava starch as a binder in the production of paracetamol tablets using wet granulation method](#)

Agatha Budi Susiana Lestari *, Rika Eliana

Page : 1918-1929

[↓ PDF](#)

Research Article

[12. Pharmacokinetic and biochemical properties of clindamycin compared with imipenem loaded bone cement](#)

Ban M. Ali *, Orooba M. S. Ibrahim *, Nibras N.a. Alabbas *

Page : 1930-1939

[↓ PDF](#)

Research Article

[13. Preparation and evaluation of polylactic acid/ chitosan nanofibers containing dexpanthenol on diabetic wound healing in rat](#)

Mitra Mahmoudi Meymand , Payam Khazaeli , Mohammad Khaksarihadad , Saeed Mohammad Soleymani

Page : 1940-1949

[↓ PDF](#)

Research Article

[14. Optimization of nanosilver purification process with Camellia sinensis L. extract as bioreductor](#)

Rini Dwilastuti *, Aveline Elula Dedjanto , Lutfi Chabib , Florentinus Dika Octa Riswanto

Page : 1950-1958

[↓ PDF](#)

Research Article

[15. Acrostichum aureum linn \(crosiers\): Unveiling nutritional content, phytochemical composition and anxiolytic activity through preclinical studies](#)

Research Article

[16. Inositol role in polycystic ovary syndrome \(PCOS\) and the awareness of Iraqi doctors regarding this role](#)

Haider M Badea Albadri *, Yasir Sj Alrubaye , Haidar A Abdulamir

Research Article

[18. Risk management in the sterilization process for reusable medical devices: Moroccan Hospital experience](#)

Fadela Benzag , Omar Elhamdaoui *, Ali Cherif Chefchaoui , Younes Rahali , Yassir El Alaoui

Research Article

[19. Investigating the correlations between substance P, antioxidant levels, and metabolic markers in non-obese Type 2 Diabetic patients](#)

Shahad Wisam Ahmed *, Shatha Hussein Ali

Research Article

[20. Effects of fermented calabash fruit \(Crescentia cujete L.\) on the Nissl's Body, C-RP and COX-2 in rat models with artificial-induced ischemic stroke](#)

Yos Adi Prakoso *, Achmadi Susilo , Sitarina Widyarini , Puput Ade Wahyuningtyas , Jasir Hakim Hidayah

Research Article

[21. Glibenclamide co-crystals: Development and characterization using D-mannitol and citric acid as a carrier to improve its dissolution profile](#)

Sukmarini Anugrahanti , Nindya Kusumorini *, Adhyatmika Adhyatmika

Research Article

[22. Total alkaloids and anti-inflammatory activity of Glaucium grandiflorum widely grown in Syria: A study on formalin induced paw edema in rats](#)

Nivin Alabdullah Alsheikh *, Thanaa Harami , Amina Ibrahim , Ahmad Manee

Research Article

[23. The relationship between FABP And GDF-15 levels in evaluation with syntax score to predict the complexity of coronary artery lesion](#)

Rawa M.m. Taqi *, Raid J. M. Al-timimi *, Moayed B. Hamid

Research Article

[24. Antimycobacterial activity of the secondary metabolite fraction derived from endophytic bacterium *Bacillus velezensis* strain DJ4 isolated from *Archidendron pauciflorum*](#)

Genia Sotya Sinarawadi , Jepri Agung Priyanto ^{*} , Muhammad Eka Prastyu , Zetryana Puteri Tachrim

Page : 2055-2063

[↓ PDF](#)

Research Article

[25. Immunohistochemical study of matrix metalloproteinases 2 and 9 in the placenta of spontaneous miscarriage](#)

Russul Hassan ^{*} , Mukhtar K. Haba

Page : 2064-2076

[↓ PDF](#)

Research Article

[26. Optimization of phenolic and flavonoid content from *Graptophyllum pictum* \(L.\) Griff. leaf under maceration extraction methods using response surface methodology and its antioxidant activity](#)

Sri Yuliasmi ^{*} , Jane Melita Keliat , Lokot Donna Lubis , Muhammad Fauzan Lubis

Page : 2077-2090

[↓ PDF](#)

Research Article

[27. Antioxidant and antibacterial activity of extracts and compounds from endophytic fungi isolated from roots of *Physalis angulata* and their combination effects](#)

Elfita Elfita ^{*} , Budi Eko Wahyudi , Hary Widjajanti , Salni Salni , Mardiyanto Mardiyanto , Rian Oktiansyah , Julinar Julinar

Page : 2091-2109

[↓ PDF](#)

Research Article

[28. Sesquiterpene coumarins of *Ferula tadshikorum* Pimenov](#)

Komila Eshbakova ^{*} , Kholida Khasanova ^{*} , Kurbonazar Juraev , Junli Yang ^{*} , Bakhrom Komilov

Page : 2110-2116

[↓ PDF](#)

Research Article

[29. Effect of cocrystallization in augmentation of in vitro and in vivo performance of irbesartan](#)

Monika Nijhawan ^{*} , Rajeswari Aleti , Sailaja Gunnam , Dr Trapti Saxena

Page : 2117-2125

[↓ PDF](#)

Research Article

[30. Enhanced cytotoxicity of docetaxel delivered through folic acid grafted poloxamer P188 polymeric micelles](#)

Amol Tatode , Divya Zambre , Mohammad Qutub ^{*} , Tanvi Premchandani , Milind Umekar , Prashant Pande

Page : 2126-2142

[↓ PDF](#)

Clinical Research

[31. Identification of phytochemicals and evaluation of anticancer activity of peels of *Carica papaya* fruit](#)

Valiyakath Mohammedrafeek Rebeeda , Athilan Muhsina , Mangalath Rameesa , Hind Shareef Fathima , Thasni Shanibah , Taj Ashik ,
Vimal Kumar Shanmugavelu , Pattilthodika Suhail *

Page : 2143-2150

[↓ PDF](#)

Research Article

[32. Pharmacognostic evaluation and HPTLC quantification of rutin in Adina cordifolia leaf with profiling of anti- inflammatory, and antioxidant activities](#)

Rakesh Surappa Anjaneya *, Gunosindhu Chakraborty

Page : 2151-2164

[↓ PDF](#)

Reviews

Review

[3. Genetic scissors: A new era in gene therapy](#)

Dhanashree Sanap *

Page : 1811-1822

[↓ PDF](#)

Review

[17. Transferosomes: Advanced nanocarriers for enhanced drug delivery](#)

Sreehari Nair , Dhanashree P. Sanap *, Kisan R. Jadhav

Page : 1978-1993

[↓ PDF](#)

Review

[33. Comparative analysis of FDA-approved Alzheimer's therapies: symptomatic and disease-modifying approaches](#)

Mohammed Abdo Qasem Radman Khaled , Ayşe Nur Hazar-yavuz *

Page : 2165-2179

[↓ PDF](#)

Aim & Scope

+

Author Guidelines

+

Ethical Principles and Publication Policy

+

Price Policy

+

[Archive](#)

[Volume: 27 Issue: Current Research Topics In Pharmacy: An Overview of Novelities in Cancer Treatment , 7/9/25](#)

[Volume: 29 Issue: 5 , 9/1/25](#)



Optimization of nanosilver purification process with *Camellia sinensis* L. extract as bioreductor

Rini DWIASTUTI^{1*}, Aveline Elula DEDJANTO¹, Lutfi CHABIB², Florentinus Dika Octa RISWANTO³

¹ Department of Pharmaceutics and Pharmaceutical Technology, Faculty of Pharmacy, Sanata Dharma University, Yogyakarta, Indonesia

² Department of Pharmacy, Islamic University of Indonesia, Yogyakarta, Indonesia

³ Department of Pharmaceutical Analysis and Medicinal Chemistry, Faculty of Pharmacy, Sanata Dharma University, Yogyakarta, Indonesia

* Corresponding Author. E-mail: rini_dwi@usd.ac.id (R.D.); Tel. +62-888-6809-057

Received: 29 July 2024 / Revised: 5 November 2024 / Accepted: 7 November 2024

ABSTRACT: Nanosilver can be described as a nanoparticle synthesized from silver metal with a size range of 1–100 nm. Nanosilver synthesis can be performed using green tea leaf extract (*Camellia sinensis* L.) as a bioreductor due to its flavonoid content. The content of flavonoid compounds is able to reduce silver metal ions (Ag^+) derived from AgNO_3 as metal precursors so that silver nanoparticles can be produced. This study aimed to obtain the optimum time and speed of centrifugation in nanosilver purification with green tea leaf bioreductors using the Central Composite Design (CCD) method. This study used two independent variables namely the duration and speed of centrifugation. The effect of centrifugation duration and speed on wavelength, transmittance percentage, and particle size of purified were analyzed by response surface methodology using the R software. The duration and speed of the optimum formula for the nanosilver purification process were obtained using the CCD method. The optimum conditions obtained were the centrifugation duration of 22 minutes and the centrifugation speed of 3500 rpm. Furthermore, the content of tannin compounds in green tea leaves was determined using thin layer chromatography.

KEYWORDS: Nanosilver; green tea leaves; CCD; sonication; purification; tannin.

1. INTRODUCTION

Nanoparticle technology is currently being developed in Indonesia for various applications. Nanoparticles are a part of nanotechnology that develops particles of a pharmaceutical preparation in the size range of 1–1000 nm in a delivery system that can be transferred through diffusion, while increasing the affinity of the system by increasing the contact area. One type of nanoparticle that can be used in pharmaceutical preparations is nanosilver. Nanosilver preparations are nanoparticles produced from silver metal, which have a size of 1–100 nm [1, 2]. Pure particles can be synthesized using physical and chemical methods. However, these methods are expensive and not environmentally friendly. A new method that can be used is biosynthesis using plants as bioreductors, which is more environmentally friendly, simpler, and inexpensive because it uses natural materials (Green Synthesis) and is widespread in Indonesia [3, 4].

Plant organic compounds used as bioreducing agent can help reduce silver ions in metal precursor compounds, such as AgNO_3 , to form AgNPs in the synthesis process. Green tea leaves (*Camellia sinensis* L.) can be used as bioreductors because it contains flavonoid compounds. Compounds containing flavonoids have hydroxyl groups ($-\text{OH}$) and the ability to bind metals that are oxidized to carbonyl groups ($\text{C}=\text{O}$). The hydroxyl functional group can act as a reductant by donating electrons to Ag^+ ions to produce Ag nanoparticles [5]. A plant extract was used as the reducing agent. Green-tea-leaf extract contains secondary metabolites that act as reductants by reducing Ag metal ions. The secondary metabolites found in green tea leaf extracts are terpenoids, alkaloids, phenols, and flavonoids. Flavonoids that are abundant in green tea leaf extract can be used as antioxidants because they are easily oxidized to facilitate the formation of AgNPs by reducing silver metal ions Ag^+ to Ag [6].

If the synthesis is successful, a purification process is required to separate the impurities from the solution by centrifugation. Based on the research conducted by Basule (2021), purification of nanosilver

How to cite this article: Dwiastuti R, Dedjanto AE, Chabib L, Riswanto FDO. Optimization of nanosilver purification process with *Camellia sinensis* L. extract as bioreductor. J Res Pharm. 2025; 29(5): 1950-1958.

synthesis was performed by centrifugation at 2000 rpm for 10 min [7]. The wavelength of the nanosilver after purification was greater than that before purification. This increase in wavelength occurred because the stability of the nanosilver particles formed is lower after the purification process [8]. This low stability is caused by the high ion content in the nanosilver solution, which allows it to form a new nanosilver colloidal system [9]. Hence, it is necessary to optimize the duration and speed of centrifugation to obtain nanosilver particles of suitable particle sizes. The optimization design used in this study was a central composite design (CCD). This design was used to evaluate the effects of a combination of two or more treatments. CCD was chosen in this study because it does not require much time or energy to conduct experiments, even though it has a larger number of levels to maximize the expected response and can provide a relationship between the independent and dependent variables [10].

Based on the above description, the optimal duration and speed of centrifugation for nanosilver purification must be determined to obtain an acceptable response, including satisfactory wavelength and transmittance percentage [11]. This study aimed to optimize the nanosilver purification process, including the duration and speed of centrifugation, using the CCD approach.

2. RESULTS

Extraction of green tea leaves powder was performed using solid-liquid extraction at 60°C. The green tea infusion resulted in a clear brown infusion, and flavonoid compounds that can be used as bioreductors were successfully obtained [12]. A qualitative assay of flavonoids was performed using thin layer chromatography (TLC) to ensure the presence of the flavonoids rutin and tannin in the green tea leaf infusions. Rutin standard displayed an R_f value of 0.51 and tannin standard displayed an R_f value of 0.76 while the *C. sinensis* extract presented an R_f value of 0.36 in the first spot and 0.73 in the second spot. The TLC are shown in Figure 1.

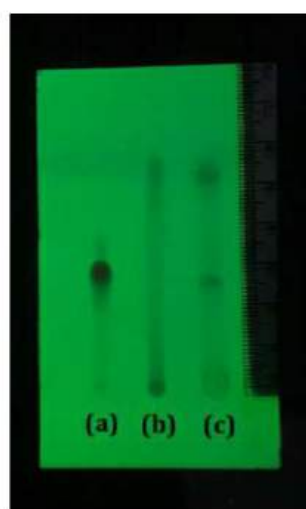


Figure 1. KLT results of rutin standard (a), tannin standard (b), and *Camellia sinensis* extract at a detected wavelength. Mobile phase: butanol acetic acid in a mixture 4:1 (v/v). Stationary phase: silica gel GF₂₅₄. The elution distance was 7.5 cm.

In the early stages, the mixture of *C. sinensis* extract and AgNO₃ appeared light yellow. Changes in color from bright yellow to yellowish-brown indicate the presence of nanosilver [13]. In accordance with previous research, it was reported that a brownish color change occurred because of surface plasmon resonance (SPR), which indicated the presence of a silver ion-reducing process [14]. SPR is an optical sensor that uses surface plasmon waves to observe the interaction between a metal (silver) surface and a dielectric material [15]. Table 1 presents the experimental design using the CCD approximation and the obtained responses, such as the wavelength and percentage transmittance. The higher transmittance percentage indicates the higher quality of nanoproducts [16]. The formation of silver (Ag⁰) nanoparticles was indicated by the absorption peak at a wavelength of 434–444 nm [17]. The maximum absorbance wavelength in this study was in the range of 434–444 nm, which proves that the mixing ratio of the two materials between a

solution of silver nitrate and green tea extract was successfully synthesized (Figure 2). The obtained percentage also met the target of 91–99%.

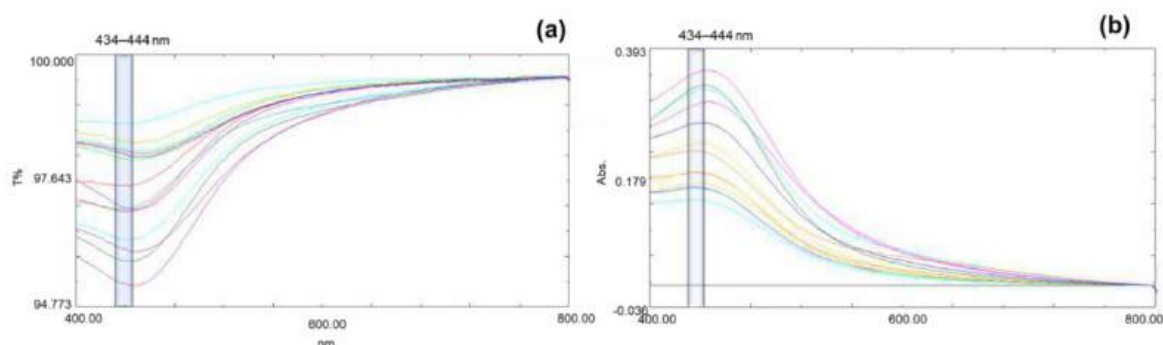


Figure 2. UV-visible spectra of the synthesized product containing silver nitrate and green tea extract in transmittance mode (a) and absorbance mode (b). The blue area indicates the maximum absorbance wavelength of 434–444 nm.

Table 1. An experimental design utilizing the CCD model and responses acquired after purification

| Run Order | Independent variables | | Dependent variables | |
|-----------|-----------------------|-------------|---------------------|-------------------|
| | Duration (minutes) | Speed (rpm) | Wavelength (nm) | Transmittance (%) |
| 1 | 15 | 3500 | 444 | 95.798 |
| 2 | 15 | 3500 | 440 | 96.945 |
| 3 | 10 | 5000 | 438 | 97.534 |
| 4 | 20 | 5000 | 434 | 97.002 |
| 5 | 20 | 2000 | 446 | 95.251 |
| 6 | 15 | 3500 | 442 | 96.288 |
| 7 | 10 | 2000 | 448 | 96.040 |
| 8 | 15 | 5600 | 270 | 98.935 |
| 9 | 15 | 1500 | 444 | 96.977 |
| 10 | 15 | 3500 | 438 | 98.103 |
| 11 | 22 | 3500 | 436 | 98.509 |
| 12 | 8 | 3500 | 438 | 98.187 |
| 13 | 15 | 3500 | 436 | 98.318 |
| 14 | 15 | 3500 | 438 | 98.257 |

The synthesis and purification processes can produce nanoparticles. This can be proven by conducting particle size tests using a particle size analyzer (PSA). This test proved that the nanosilver preparation successfully achieved a size range of 1–100 nm. Figure 3 shows the particle size and size distribution after synthesis for 15 min (before purification) and after purification for 10 min at 2000 rpm. The particle sizes were a size of 82.3 nm (before purification) and 63,5 nm (after purification). The results indicated purification process caused the smaller size of nanosilver. This phenomenon may occur due to the impurities removal in the purification process.

A CCD was used to optimize the duration and speed of centrifugation during the nanosilver purification process. This CCD design had 14 experimental runs and 6 replications in the design recommended by the model. The regression analysis of the response surface for both the wavelength and percentage transmittance is presented in Table 2. The response surface model showed significant results ($p < 0.05$). The design model had no real or significant effect on the wavelength response and percentage transmittance of the nanosilver, where both responses had P-values of 0.11 and 0.6669 respectively. The R^2 and R^2 (adj) values obtained were greater than 5%, and the variables did not significantly affect the wavelength response and percentage transmittance. Figure 4 shows a contour plot of the wavelength and transmittance as functions of the duration and speed of centrifugation. The Lack of Fit of the wavelength response was significant, indicating that the wavelength response could not be predicted using the model. However, the percentage transmittance response was not significant, indicating that the response can be predicted using this model and that it is suitable as an optimization model for the nanosilver purification

process [18]. The appearance of the wavelength surface plot and the percentage transmittance between the duration and centrifugation speed are depicted in Figure 5.

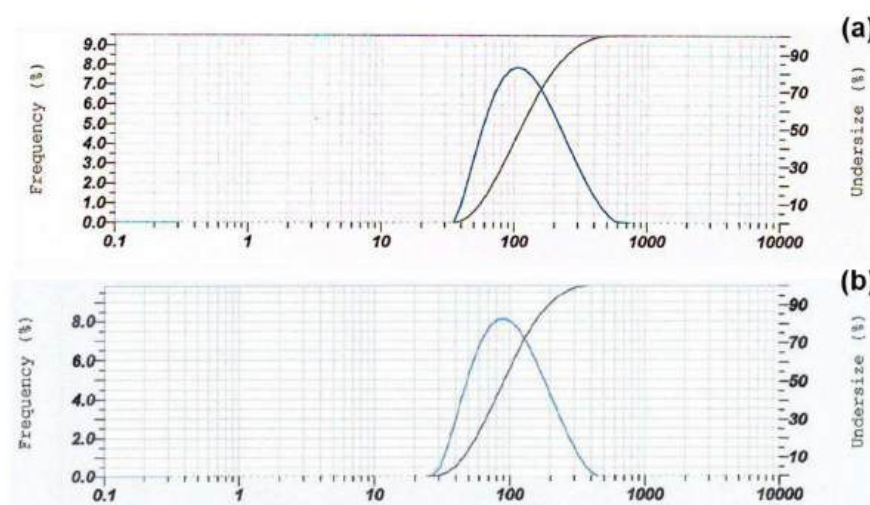


Figure 3. Representative results of particle size analysis of nanosilver before (a) and after (b) purification process

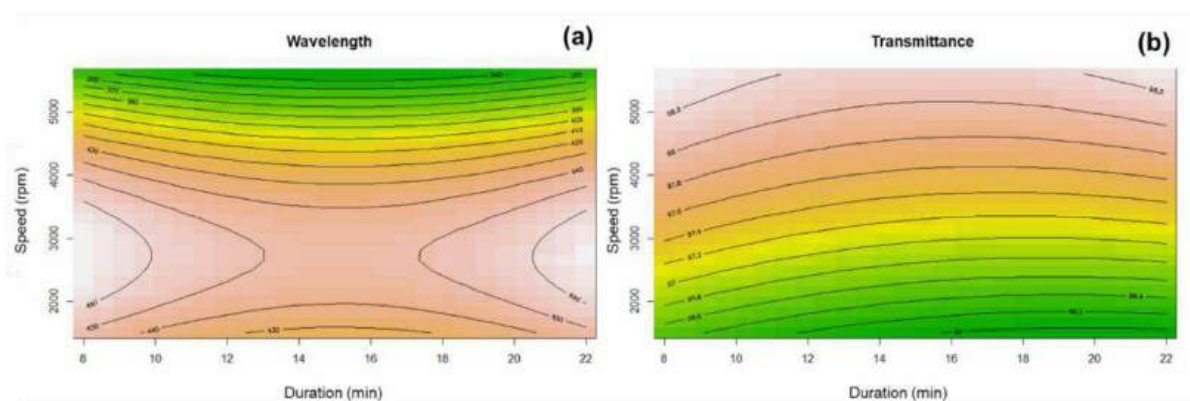


Figure 4. Contour plot of the wavelength (a) and transmittance (b) for duration versus speed of centrifugation.

The optimum formula was optimized using R software, as has never been done in previous studies. This was inferred to result in a desirability value for the composite of 0.643 at a duration of 22 min and a speed of 3500 rpm. A desirability value close to 1 implies a high ability of the model to produce the desired value. Figure 6 presents a plot of the optimization surface for both responses involving wavelength and percentage transmittance. The optimum formula for the production of nano silver was determined using the RSM model. The results of the observations using six replicates for each formula are presented in Table 3. The RSD values, which indicate random errors in measuring the observation results for wavelength and transmittance before purification, were 2.04% and 0.75%, respectively. The RSD values for wavelength and transmittance after purification were 2.94% and 0.217%, respectively. These results revealed that the optimum formula for nanosilver particles was reached.

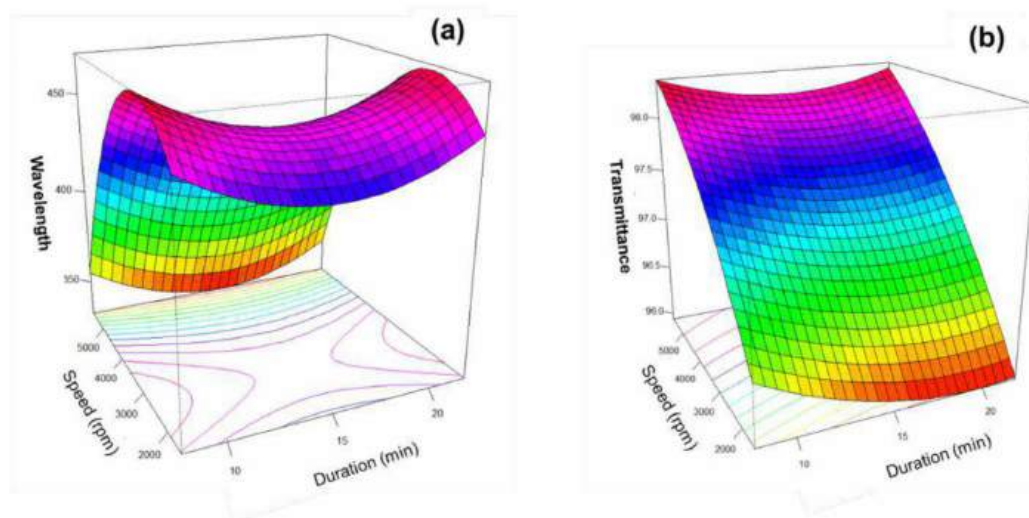


Figure 5. Surface plot of wavelength and transmittance percentage between duration versus speed of centrifugation.

Table 2. Regression analysis results of response surface for wavelength and percentage transmittance.

| Response | P-value | R ² | R ² (Adj) | Lack of Fit |
|---------------|---------|----------------|----------------------|------------------------|
| Wavelength | 0.11 | 0.6195 | 0.3817 | 2.328.10 ⁻⁶ |
| Transmittance | 0.6669 | 0.2906 | -0.1528 | 0.2864 |

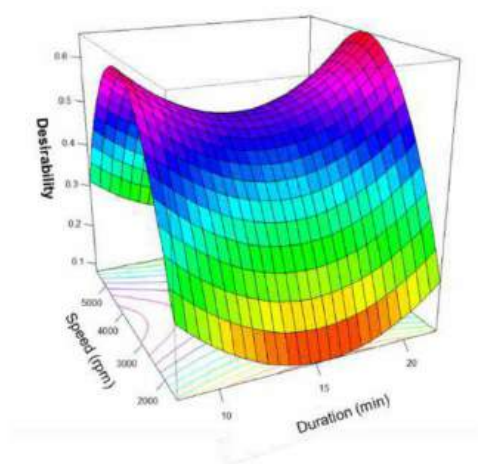


Figure 6. Surface plot of both responses versus desirability

3. DISCUSSION

The solvent used in the extraction process was selected based on having the same polarity as the flavonoid compounds, according to the principle of dissolution. In accordance with this principle, the solvent used was redistilled water because it has similar polarity properties to those of most flavonoid compounds that can dissolve in water. Redistilled water was also chosen because it is readily available, inexpensive, and nonvolatile. The green tea leaf extract contained tannins, as indicated by the closely related R_f values for the reference standard and *C. sinensis* extract. R_f values between samples and rutin standards were considerably different because of the small content of rutin contained in green tea leaves compared with the other compounds. Nanosilver synthesis by the sonication method can form nano-sized particles in

Table 3. Optimal formula test results on response wavelength and percentage transmittance.

| No | Before Purification | | After Purification | |
|------|---------------------|-------------------|--------------------|-------------------|
| | Wavelength (nm) | transmittance (%) | Wavelength (nm) | transmittance (%) |
| 1 | 432 | 94.754 | 438 | 98.409 |
| 2 | 430 | 94.467 | 440 | 98.134 |
| 3 | 435 | 96.117 | 436 | 98.624 |
| 4 | 434 | 96.242 | 434 | 98.065 |
| 5 | 430 | 95.726 | 432 | 98.344 |
| 6 | 432 | 95.985 | 434 | 98.112 |
| Mean | 432.167 | 95.549 | 435.667 | 98.281 |
| SD | 2.040 | 0.750 | 2.940 | 0.217 |
| RSD | 0.47% | 0.78% | 0.68% | 0.22% |

the wavelength range of 400–450 nm, which indicates the presence of nanosilver. The sonication method converts electrical signals into physical vibrations in the presence of ultrasonic electricity such that the particles break into smaller particles. The formation of nanosilver with smaller size led to shorter wavelengths with increased monodispersity [19].

Purification was performed after nanosilver synthesis to remove impurities. Nanosilver purification was conducted by centrifugation at a specific speed and duration based on the optimal design. Centrifugation was used to remove impurities and large particles in the nanosilver preparation. An increase in the wavelength was observed before and after purification. This increase in wavelength suggests that the nanosilver particle size increased because of delocalized and exchanged electron conduction on the particle surface, which caused a redshift [17]. Nanosilver was characterized using a UV-Vis double-beam spectrophotometer to determine the optimum wavelength and percentage transmittance for nanosilver formation. These two responses were analyzed before and after purification. This indicated that silver ions (Ag^+) were completely reduced to Ag or nanosilver. The percentage transmittance was observed to quantitatively measure the clarity of the solution. Both showed that the nanosilver solution was successfully synthesized and had a nano size.

The transmittance percentage, which was close to 100%, indicates that the particle size of the nanosilver formed decreased. If the particle size is smaller, the subsequent Brownian motion is faster, which prevents the sedimentation process and causes the solution to become clearer [20]. The absorbance was inversely proportional to the transmittance percentage. The higher the percentage transmittance, the lower the absorbance. The absorbance value indicates the amount of nanosilver formed: the lower the absorbance value, the less nanosilver is formed. Wavelengths that did not reach the target occurred because of the high centrifugation speed during the purification process, causing agglomeration and low stability [3]. In addition, the purification process removes the capping agent from the surface of the nanosilver so that clumping or aggregation occurs, causing nonuniform nanoparticle sizes because the SPR energy shifts to a lower energy level.

The experimental data and responses were analyzed and evaluated using R software. The software analyzed the model that best suited the response conditions so that it will determine the optimal point of the given response. After obtaining the optimization results, validation was performed to determine the level of accuracy of the optimization model. A p-value that does not coincide or is above 0.05 indicates that the difference produced out of the model is not significant. This could have occurred because the wavelength response and percentage transmittance in all experiments were still in the optimum wavelength range of the nanosilver, and there was no significant difference such that neither response could be predicted. The adjusted R^2 value could decrease if the variables added to the model had no effect.

A model suitability test was conducted to determine whether the model was in accordance with the predicted model by examining the lack of fit (inaccuracy) in a response. The experimental results of 13 experiments have wavelengths that meet the target wavelength of nanosilver, and only one experiment does not meet the target wavelength; therefore, this model can still be used. The resulting plot shows the response area of the centrifugation duration and speed in the nanosilver purification process using a green tea leaf

extract bioreductor. The optimized areas have various colors that show the area of the wavelength response and percentage transmittance. The three-dimensional surface wavelength response was curved downward, indicating that the area had the maximum response resulting from the independent variables.

Optimization provides the best results by finding variable values that are considered optimal, effective, and efficient for achieving the desired results [21]. The test results of centrifugation duration and speed that have been performed are then entered into the software and then the optimum point of the response given in the most suitable model will be recommended. The optimum point was obtained from the highest combined desirability value, which was considered the optimal condition. The highest desirability value from the predicted optimization process was 0.643 for a duration of 22 min and a speed of 3500 rpm. This indicated that 64.3% of the software's ability to produce the best condition combines all the objective functions.

Data validation was the final stage of the optimization process and is required to test the accuracy of the model in describing certain conditions. In this study, the validation was performed by comparing the prediction results obtained from the software with the research results after six replicates. All replications obtained RSD at the wavelength and percentage transmittance that met the requirements, so that it can be said that the replicated data had good precision.

4. CONCLUSIONS

The optimum centrifugation duration and speed in nanosilver purification was achieved by the CCD approach. The optimal conditions attained in this research were a duration of 22 min and a speed of 3500 rpm. This condition has a composite desirability result which is 0.643 in the process of computational optimization. Observation of the formulation under optimum conditions resulted in favorable repeatability with prediction errors that were <2% for the response of wavelength and percentage of transmittance. Further, the purification process in nanosilver formulation enable the removal of unwanted substances or contaminants that may have formed during synthesis stages, such as residual reactant materials or binding agents.

5. MATERIALS AND METHODS

5.1. Experimental Section

Some of the materials used in this study were green tea leaves (*C. sinensis* L.) from Kepala Djenggot (production code 09022211HC3), filter paper; AgNO₃ pro analysis; distilled water; and pharmaceutical grade butanol, acetic acid, tannin, and rutin (Merck Millipore). The equipments required for this study were glassware (PT. Iwaki Glass), thermometer, analytical balance (Ohaus), UV-Vis spectrophotometer (Shimadzu UV-Vis 1800), hot plate (Thermo Scientific), GF254 TLC plate (Merck), vortex (Thermo Scientific), a centrifuge (Thermo Scientific), microtube, pipette pump, micropipettes, and R software with the package of 'rsm.'

5.2. Methods

5.2.1. Extraction of green tea leaves

A total of 100 mL of redistilled water was heated to 60°C. Thereafter, the green tea leaf (*C. sinensis* L.) powder of 0.2 g was put into the aqueous and heated for 20 minutes at 60°C followed by stirring. The resulting solution was filtered [22].

5.2.2. Qualitative test by thin layer chromatography

The mobile phase butanol-acetic acid at a ratio of 4:1 (v/v) was prepared by blending both materials and then shaking [17]. The mobile phase was placed in a chromatography chamber and saturated for 1 h. The stationary phase used in this study was silica gel GF254 thin-layer chromatography, with a measurement of 6 × 10 cm and an elution separation of 7.5 cm. The plate was then heated at 110°C for 30 min. The samples, tannin standard comparator, and rutin reference standard were dotted 2 cm from the bottom edge of the plate. After saturation with the eluent, the chromatography plate was placed in the chamber and eluted with the mobile phase to a certain volume. After elution, plates were examined under UV light at 254 nm. The RF value was then measured [23].

5.2.3. Preparation of AgNO₃ solution

The solid AgNO_3 (0.169 g) was dissolved in distilled water. The solution was poured into a 100 mL volumetric flask, and distilled water was added to the volume, which was then shaken until completely dissolved. The solution was diluted by transferring 20 mL of the solution to a 200 mL volumetric flask and adding distilled water, which was then shaken until completely solvated [22].

5.2.4. Nanosilver purification optimization design

The variation of centrifugation duration and speed according to Basule (2021) which have been modified [7]. The duration and speed of centrifugation for nanosilver purification were determined using a two-factor, five-level CCD. Table 4 shows the duration and speed of centrifugation at each experimental level. The optimization in this study utilized R software, which has an experimental design that conducts 14 experiments to generate an optimization in this model.

Table 4. Optimized factors utilizing the method of CCD

| Factors | Experimental stage of CCD | | | | |
|-------------------|---------------------------|------|------|------|------|
| | (-α) | (-1) | (0) | (+1) | (+α) |
| Duration (minute) | 8 | 10 | 15 | 20 | 22 |
| Speed (rpm) | 1500 | 2000 | 3500 | 5000 | 5600 |

5.2.5. Synthesis and purification of nanosilver

Three milliliters of green tea leaves solution was mixed with 27 mL of AgNO_3 solution followed by heating process in a sonicator bath at 80°C for 15 minutes. This method was developed by modifying the approach from an earlier study [7]. Nanosilver was purified by centrifuging the colloid for a specific duration and speed. The supernatants from the centrifugation were examined for wavelength, percent transmittance, and particle size [8].

5.2.6. Characterization of nanosilver

The nanosilver formed was characterized using a UV-Vis spectrophotometer in the 400–450 nm wavelength range [6]. Maximum absorbance wavelength and transmittance measurements were conducted using a UV-Vis spectrophotometer. Total sample of nano silver (100 μL) was solvated in 5 mL distilled water on the reaction tube and swirled by vortexing for 1 min. The absorbance of the samples was measured at the optimal wavelength. Redistilled water was used as the blank [20].

5.2.7. Statistical analysis

The optimization process was implemented using the CCD method (two factors and five levels). The results of this study were optimized with RSM using R software.

Acknowledgements: This research is funded by Program Penelitian Pusat Studi Universitas Sanata Dharma 2023 that awarded to Dr. apt. Rini Dwiastuti, M.Sc. (No.: 012/Penel/LPPM-USD/II/2023).

Author contributions: Concept – R.D.; Design –F.D.O.R.; Supervision – R.D.; Resource – R.D., A.E.D, L.C., F.D.O.R.; Materials – R.D.; Data Collection &/or Processing – A.E.D., L.C. ; Analysis &/or Interpretation – A.E.D., L.C.; Literature Search – A.E.D.; Writing – R.D., A.E.D, F.D.O.R. ; Critical Reviews – R.D., A.E.D, L.C., F.D.O.R.

Conflict of interest statement: The authors declare without conflict of any interests.

REFERENCES

- [1] Ge L, Li Q, Wang M, Ouyang J, Li X, Xing MMQ. Nanosilver particles in medical applications: Synthesis, performance, and toxicity. *Int J Nanomedicine*. 2014; 9(1): 2399–2407. <https://doi.org/10.2147/IJN.S55015>.
- [2] Eze FN, Eze RC, Singh S, Okpara KE. Fabrication of a versatile and efficient ultraviolet blocking biodegradable composite film consisting of Tara gum/PVA/Riceberry phenolics reinforced with biogenic riceberry phenolic-rich extract-nano-silver. *Int J Biol Macromol*. 2024; 278(3): 134914. <https://doi.org/10.1016/j.IJBIOMAC.2024.134914>.
- [3] Rahim DM, Herawati N, Hasri H. Sintesis Nanopartikel Perak Menggunakan Bioreduktor Ekstrak Daun Teh Hijau (*Camellia Sinensis*) dengan Iradiasi Microwave. *Chem J Ilm Kim dan Pendidik Kim*. 2020; 21(1): 30–41. <https://doi.org/10.35580/CHEMICA.V21I1.14835>.
- [4] Dwiastuti R, Irnandari E, Gani MR, Yuliani SH, Nastiti CMRR. Optimization of nanosilver synthesis process with bioreductor of binahong leaf extract (*Anredera cordifolia* (Ten.) Steenis). *J Pharm Sci Community*. 2022; 19(2): 62–70.

- <https://doi.org/10.24071/jpsc.004465>.
- [5] Ovais M, Khalil AT, Islam NU, Ahmad I, Ayaz M, Saravanan M, Shinwari ZK, Mukherjee, S. Role of plant phytochemicals and microbial enzymes in biosynthesis of metallic nanoparticles. *Appl Microbiol Biotechnol*. 2018; 102: 6799–6814. <https://doi.org/10.1007/S00253-018-9146-7>.
- [6] Ibnu Fajar R, Putu Wrasati L, Suhendra L. The content of the flavonoid compound and antioxidant activity of green tea extract in the treatment temperature and time brewing. *J Rekayasa dan Manaj Agroindustri*. 2018; 6(3): 196–202. <https://doi.org/10.24843/JRMA.2018.V06.I03.P02>.
- [7] Basule V. Bachelor Thesis. *Optimasi Proses Sonikasi pada Sintesis Nanosilver dengan Bioreduktor Ekstrak Daun Teh Hijau (Camellia sinensis L.)*. Department of Pharmaceutical Technology, Faculty of Pharmacy, Sanata Dharma University, Yogyakarta, Indonesia, 2021.
- [8] Dewi KTA, Kartini, Sukweenadhi J, Avanti C. Karakter Fisik dan Aktivitas Antibakteri Nanopartikel Perak Hasil Green Synthesis Menggunakan Ekstrak Air Daun Sendok (*Plantago major* L.). *Pharm Sci Res*. 2019; 6(2): 69–81. <https://doi.org/10.7454/psr.v6i2.4220>.
- [9] Valenti LE, Giacomelli CE. Stability of silver nanoparticles: agglomeration and oxidation in biological relevant conditions. *J Nanoparticle Res*. 2017; 19: 156. <https://doi.org/10.1007/S11051-017-3860-4>.
- [10] Riswanto FDO, Rohman A, Pramono S, Martono, S. Application of response surface methodology as mathematical and statistical tools in natural product research. *J Appl Pharm Sci*. 2019; 9(10): 125–133. <https://doi.org/10.7324/JAPS.2019.91018>.
- [11] Samson O, Adeeko TO, Makama EK. Synthesis and optical characterization of silver nanoparticles (Ag-NPs) thin films (TFs) prepared by silar technique. *Int J Curr Res Acad Rev*. 2017; 5(12): 15–24. <https://doi.org/10.20546/IJCRR.2017.512.003>.
- [12] Verdiana M, Widarta IWR, Permana IDGM. Pengaruh Jenis Pelarut Pada Ekstraksi Menggunakan Gelombang Ultrasonik Terhadap Aktivitas Antioksidan Ekstrak Kulit Buah Lemon (*Citrus Limon* (Linn.) Burm F.). *J Ilmu dan Teknol Pangan*. 2018; 7(4): 213–222. <https://doi.org/10.24843/ITEPA.2018.V07.I04.P08>.
- [13] Eze FN, Jayeoye TJ, Tola AJ. Fabrication of label-free and eco-friendly ROS optical sensor with potent antioxidant properties for sensitive hydrogen peroxide detection in human plasma. *Colloids Surfaces B Biointerfaces*. 2021; 204: 111798. <https://doi.org/10.1016/J.COLSURFB.2021.111798>.
- [14] Eze FN, Ovatlarnporn C, Nalinbenjapun S, Sripetthong S. Ultra-fast sustainable synthesis, optimization and characterization of guava phenolic extract functionalized nanosilver with enhanced biomimetic attributes. *Arab J Chem*. 2022; 15(10): 104167. <https://doi.org/10.1016/J.ARABJC.2022.104167>.
- [15] Rajabiah N. Surface plasmon resonance (SPR) phenomenon of the oxidizing and reducing polypyrrole. *Turbo J Progr Stud Tek Mesin*. 2016; 5(2). <https://doi.org/10.24127/TRB.V5I2.247>.
- [16] Li B, Ye S, Stewart IE, Alvarez S, Wiley BJ. Synthesis and purification of silver nanowires to make conducting films with a transmittance of 99%. *Nano Lett*. 2015; 15(10): 6722–6726. <https://doi.org/10.1021/acs.nanolett.5b02582>.
- [17] Dwiastuti R, Suhendra PA, Yuliani SH, Riswanto FDO. Application of the central composite design approach for optimization of the nanosilver formula using a natural bioreductor from *Camellia sinensis* L. extract. *J Appl Pharm Sci*. 2022; 12: 48–56. <https://doi.org/10.7324/JAPS.2022.120806>.
- [18] Hendrawan Y, Susilo B, Putranto AW, Riza DMFA, Maharani DM, Amri MN. Optimasi Dengan Algoritma RSM-CCD Pada Evaporator Vakum Waterjet Dengan Pengendali Suhu Fuzzy Pada Pembuatan Permen Susu. *AgriTECH*. 2016; 36(2): 226–232. <https://doi.org/10.22146/AGRITECH.12868>.
- [19] Nouri A, Tavakkoli Yarak M, Lajevardi A, Rezaei Z, Ghorbanpour M, Tanzifi M. Ultrasonic-assisted green synthesis of silver nanoparticles using *Mentha aquatica* leaf extract for enhanced antibacterial properties and catalytic activity. *Colloid Interface Sci Commun*. 2020; 35: 100252. <https://doi.org/10.1016/J.COLCOM.2020.100252>.
- [20] Abdassah M. Nanopartikel dengan gelas ionik. *J Farmaka*. 2017; 15(1): 45–52. <https://doi.org/10.24198/jf.v15i1.12138>.
- [21] Eze FN, Jayeoye TJ, Eze RC. Construction, characterization and application of locust bean gum/Phyllanthus reticulatus anthocyanin - based plasmonic silver nanocomposite for sensitive detection of ferrous ions. *Environ Res*. 2023; 228: 115864. <https://doi.org/10.1016/J.ENVRES.2023.115864>.
- [22] Rengga WDP, Yufitasari A, Adi W. Synthesis of silver nanoparticles from silver nitrate solution using green tea extract (*Camellia sinensis*) as bioreductor. *J Bahan Alam Terbarukan*. 2017; 6: 32–38. <https://doi.org/10.15294/jbat.v6i1.6628>.
- [23] Rakhmat II, Yuslianti ER, Alatas F. Isolasi Senyawa Aktif Flavonoid Rutin Madu Sebagai Metabolit Sekunder Bahan Baku Pengembangan Obat Diabetes Melitus. *Med Sains J Ilm Kefarmasian*. 2020; 5(1): 43–50. <https://doi.org/10.37874/ms.v5i1.149>.