NANOFORMULASI EKSTRAK KARA BENGUK (*Mucuna pruriens*) MENGGUNAKAN *NANOSTRUCTURED LIPID CARRIER* BERBASIS SETIL PALMITAT DAN ASAM OLEAT SEBAGAI KANDIDAT OBAT PARKINSON

SKRIPSI

diajukan untuk memenuhi sebagian syarat memperoleh gelar Sarjana Sains
Program Studi Kimia

Oleh
Maya Lianawati
1906071

KELOMPOK BIDANG KAJIAN HAYATI
PROGRAM STUDI KIMIA
FAKULTAS PENDIDIKAN MATEMATIKA DAN ILMU PENGETAHUAN ALAM
UNIVERSITAS PENDIDIKAN INDONESIA
2023

NANOFORMULASI EKSTRAK KARA BENGUK (*Mucuna pruriens*) MENGGUNAKAN *NANOSTRUCTURED LIPID CARRIER* BERBASIS SETIL PALMITAT DAN ASAM OLEAT SEBAGAI KANDIDAT OBAT PARKINSON

Oleh

Maya Lianawati

Skripsi ini diajukan untuk memenuhi salah satu syarat memperoleh gelar Sarjana Sains pada Program Studi Kimia Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam

Universitas Pendidikan Indonesia

Agustus 2023

LEMBAR PENGESAHAN

NANOFORMULASI EKSTRAK KARA BENGUK (*Mucuna pruriens*) MENGGUNAKAN *NANOSTRUCTURED LIPID CARRIER* BERBASIS SETIL PALMITAT DAN ASAM OLEAT SEBAGAI KANDIDAT OBAT PARKINSON

Maya Lianawati

1906071

Disetujui dan disahkan oleh pembimbing,

Pembimbing I

Prof. Dr. Ratnaningsih Eko Sardjono, M.Si.

NIP. 196904191992032002

Pembimbing II

Vidia Afina Nuraini, M.Sc.

NIP. 199307052020122009

Mengetahui,

Ketua Program Studi Kimia FPMIPA UPI

Prof. Fitri Khoerunnisa, Ph.D.

NIP. 197806282001122001

PERNYATAAN

Dengan ini saya menyatakan bahwa skripsi dengan judul "**Nanoformulasi Ekstrak Karabenguk (*Mucuna pruriens*) menggunakan *Nanostructured Lipid Carrier* berbasis Setil Palmitat dan Asam Oleat sebagai Kandidat Obat Parkinson**" beserta seluruh isinya adalah benar-benar karya saya sendiri. Saya tidak melakukan pengutipan atau penjiplakan dengan cara-cara yang tidak sesuai dengan etika keilmuan yang berlaku dalam masyarakat keilmuan. Atas pernyataan ini, saya siap menerima risiko atau sanksi apabila dikemudian hari ditemukan adanya pelanggaran etika keilmuan atau ada klaim dari pihak lain terhadap keaslian karya saya.

Bandung, Agustus 2023

Yang membuat pernyataan,

Maya Lianawati

NIM. 1906071

KATA PENGANTAR

Puji dan syukur penulis haturkan kepada Allah SWT yang telah melimpahkan rahmat, karunia, dan hidayahNya sehingga penulis dapat menyelesaikan skripsi yang berjudul "Nanoformulasi Ekstrak Kara Benguk (*Mucuna pruriens*) menggunakan *Nanostructured Lipid Carrier* berbasis Setil Palmitat dan Asam Oleat sebagai Kandidat Obat Parkinson". Shalawat dan salam semoga senantiasa tercurahkan kepada Nabi Muhammad SAW beserta seluruh keluarga, sahabat, dan umatnya hingga akhir zaman. Aamiin.

Skripsi ini disusun untuk memenuhi salah satu syarat memperoleh gelar Sarjana Sains di Program Studi Kimia, Fakultas Pendidikan Matematika dan Ilmu Pengetahuan Alam, Universitas Pendidikan Indonesia. Penulis berharap skripsi ini dapat memberikan wawasan dan manfaat bagi penulis maupun pembaca. Penulis menyadari bahwa masih terdapat kekurangan dalam penyusunan skripsi ini, oleh karena itu segala saran dan kritik yang membangun dari berbagai pihak senantiasa diharapkan untuk perbaikan di masa yang akan datang.

Bandung, Agustus 2023

Penulis

UCAPAN TERIMA KASIH

Segala puji dan syukur kehadirat Tuhan Yang Maha Esa karena berkat rahmat dan karunia-Nya penulis dapat menyelesaikan skripsi yang berjudul **"Nanoformulasi Ekstrak Kara Benguk (*Mucuna pruriens*) menggunakan *Nanostructured Lipid Carrier* Berbasis Setil Palmitat dan Asam Oleat sebagai Kandidat Obat Parkinson"** dengan lancar dan tepat waktu.

Pada proses penulisan skripsi ini, penulis mendapat berbagai bantuan dan dukungan dalam berbagai bentuk baik secara langsung maupun tidak langsung. Untuk itu penulis menyampaikan rasa hormat dan ucapan terima kasih kepada:

1. Bapak Didin, Mamah Ocah, Bapak Dindin, Ibu Hanny, serta seluruh keluarga yang senantiasa memberikan do'a dan dukungan penuh kepada penulis. Terima kasih atas segala pengorbanan kalian hingga detik ini dan seterusnya.
2. Ibu Prof. Dr. Ratnaningsih Eko Sardjono, M.Si. selaku dosen pembimbing I yang telah memberikan kesempatan, bimbingan, ilmu, saran, dan waktunya selama proses penelitian dan penyusunan skripsi ini.
3. Ibu Vidia Afina Nuraini, M.Sc. selaku dosen pembimbing II yang turut membimbing, memberikan saran dan kritik yang membangun bagi penulis.
4. Ibu Fitri Khoerunnisa, Ph.D. selaku Ketua Program Studi Kimia serta Bapak Gun Gun Gumilar, M.Si. selaku koordinator KBK Kimia Hayati yang telah memberikan ilmu yang bermanfaat selama masa perkuliahan.
5. Ibu Dr. Heli Siti Halimatul Munawaroh, M.Si. selaku dosen pembimbing akademik yang telah memberikan arahan dan motivasi bagi penulis selama menempuh studi.
6. Seluruh Dosen, Staf, dan Laboran Program Studi Kimia FPMIPA UPI yang telah memberikan banyak ilmu dan bantuan kepada penulis selama masa perkuliahan.
7. Ramdhan Gunawan, Nyoman Ayu Kristinawati, Raden Melvin Fauzan Idat, Salma Rahmadianti, dan Ibu Lilis Sumiyati selaku rekan satu tim yang telah saling membantu dan menjadi tempat berdiskusi selama proses penelitian.

8. Kinanti Aulia Putri, Salsabila Yaafi Saniyyah, Siti Aisah Nurmilah, Widya Prasetyawati Septiani, dan Zahrah Rufaida yang selalu memberikan dukungan dan mendengarkan keluh kesah penulis selama masa studi.
9. Teman-teman Kimia-C 2019 dan KBK Kimia Hayati yang telah menemani penulis selama proses studi.
10. Semua pihak yang tidak dapat disebutkan satu persatu yang telah membantu penulis hingga dapat menyelesaikan studi ini.

ABSTRAK

Kara benguk (*Mucuna pruriens*) merupakan tanaman dari famili *Fabaceae* yang mengandung L-dopa. L-dopa merupakan prekursor dopamin yang banyak digunakan untuk terapi penyakit Parkinson, suatu penyakit neurodegeneratif yang disebabkan oleh gangguan produksi dopamin. Nanoformulasi diharapkan mampu mengatasi rendahnya bioavailabilitas dan stabilitas ekstrak *M. pruriens* sehingga dapat meningkatkan efektivitas pengobatan. Penelitian ini bertujuan untuk menentukan kondisi optimal, karakteristik, efisiensi pemuatan, kapasitas pemuatan, dan kemampuan pelepasan obat dari produk nanoformulasi ekstrak biji *M. pruriens* menggunakan *nanostructured lipid carrier* berbasis setil palmitat dan asam oleat (NLC-CP-OA-Mp). Nanoformulasi dilakukan melalui metode homogenisasi panas–ultrasonikasi dengan variasi perbandingan lipid dan *power rate* ultrasonikasi. Karakterisasi produk nanoformulasi dilakukan menggunakan PSA, FTIR, SEM, dan TEM. Pengujian efisiensi pemuatan dan kapasitas pemuatan dilakukan menggunakan spektrofotometer UV-Vis, sementara uji pelepasan obat dilakukan dengan metode kantung dialisis. Hasil penelitian menunjukkan kondisi optimal proses nanoformulasi diperoleh pada perbandingan setil palmitat terhadap asam oleat sebesar 4:6 dengan *power rate* ultrasonikasi 75%. Karakterisasi dengan PSA menunjukkan produk NLC-CP-OA-Mp memiliki ukuran partikel 124,3 nm dengan indeks polidispersitas 0,244 serta nilai potensial zeta −14,1 mV. Analisis dengan FTIR menunjukkan adanya pergeseran pada puncak serapan gugus OH, NH, dan C=O yang mengindikasikan terjadinya interaksi antara senyawa L-dopa dalam ekstrak *M. pruriens* dengan setil palmitat dan asam oleat, sementara hasil SEM dan TEM menunjukkan morfologi dan bentuk *spherical* dengan rata-rata ukuran 194,60 nm. Selain itu, diperoleh efisiensi pemuatan 68,83% dengan kapasitas pemuatan sebesar 4,25%. Uji pelepasan obat menunjukkan bahwa produk NLC-CP-OA-Mp memiliki kemampuan pelepasan senyawa bioaktif dari ekstrak *M. pruriens* hingga 18,38% pada pH 1,2 dan 62,11% pada pH 7,4 setelah 420 menit. Berdasarkan hasil yang diperoleh, produk NLC-CP-OA-Mp berpotensi dijadikan sebagai obat untuk terapi penyakit Parkinson.

Kata kunci: Kara benguk, Nanoformulasi, *Nanostructured lipid carrier*, Penyakit Parkinson

ABSTRACT

Velvet bean (Mucuna pruriens) is a plant belongs to Fabaceae family which contains L-dopa. L-dopa is a dopamine precursor which is widely used in treating Parkinson's disease, a neurodegenerative disorder caused by disruption of dopamine production. Nanoformulation process is expected to overcome poor bioavailability and stability of M. pruriens extract, thereby enhancing therapeutic efficiency. This study aimed to determine optimum condition of nanoformulation process, characteristics, loading efficiency, loading capacity, and drug release of M. pruriens extract loaded in nanostructured lipid carrier using cetyl palmitate and oleic acid (NLC-CP-OA-Mp). Nanoformulation was conducted by hot homogenization–ultrasonication method with various lipid ratios and ultrasonication power rate. Characterization of nanoformulation product were performed by PSA, FTIR, SEM, and TEM. Loading efficiency and loading capacity were analyzed using UV-Vis spectrophotometer, while drug release was evaluated by dialysis bag method. The results showed that the optimum conditions for nanoformulation process were obtained with cetyl palmitate to oleic acid ratios of 4:6 with 75% ultrasonication power rate. PSA characterization showed that NLC-CP-OA-Mp product has a particle size of 124,3 nm with polydispersity index of 0,244 and exhibit a potential zeta value of −14,1 mV. FTIR analysis showed some peak shifts of OH, NH, and C=O functional group, suggesting interactions between L-dopa in M. pruriens extract with cetyl palmitate and oleic acid, while SEM and TEM images revealed that NLC-CP-OA-Mp has a spherical morphology and shape with the average particle size of 194,60 nm. Furthermore, loading efficiency and loading capacity were found to be 68,83% and 4,25% respectively. The drug release showed that NLC-CP-OA-Mp was able to release 18,38% of active compounds from M. pruriens extract at pH 1,2 and 62,11% at pH 7,4 after 420 minutes. These results show a potential use of NLC-CP-OA-Mp as a therapeutic agent for treating Parkinson's disease.

Keywords: *Velvet bean, Nanoformulation, Nanostructured lipid carrier, Parkinson's disease*

DAFTAR ISI

DAFTAR GAMBAR

DAFTAR TABEL

DAFTAR LAMPIRAN

DAFTAR PUSTAKA

Ahmad, M. Z., Sabri, A. H. Bin, Anjani, Q. K., Domínguez-Robles, J., Abdul Latip, N., & Hamid, K. A. (2022). Design and Development of Levodopa Loaded Polymeric Nanoparticles for Intranasal Delivery. *Pharmaceuticals*, *15*(3), 1–19. https://doi.org/10.3390/ph15030370

Ajiboye, A. L., Nandi, U., Galli, M., & Trivedi, V. (2021). Olanzapine loaded nanostructured lipid carriers via high shear homogenization and ultrasonication. *Scientia Pharmaceutica*, *89*(2). https://doi.org/10.3390/scipharm89020025

Akhtar, K., Khan, S. A., Khan, S. B., & Asiri, A. M. (2018). Scanning electron microscopy: Principle and applications in nanomaterials characterization. In *Handbook of Materials Characterization* (pp. 113–145). https://doi.org/10.1007/978-3-319-92955-2_4

Aldred, J., & Nutt, J. G. (2010). Levodopa. *Encyclopedia of Movement Disorders*, 132–137. https://doi.org/10.1016/B978-0-12-374105-9.00340-3

Alexandra, S. R. (2022). *NANOENKAPSULASI EKSTRAK BIJI KARABENGUK (Mucuna pruriens) DALAM ASAM STEARAT SEBAGAI KANDIDAT OBAT ANTIPARKINSON* [Universitas Pendidikan Indonesia]. http://repository.upi.edu/81118/

Alshawwa, S. Z., Kassem, A. A., Farid, R. M., Mostafa, S. K., & Labib, G. S. (2022). Nanocarrier Drug Delivery Systems: Characterization, Limitations, Future Perspectives and Implementation of Artificial Intelligence. *Pharmaceutics*, *14*(4), 883. https://doi.org/10.3390/pharmaceutics14040883

Anindya, L. (2018). Particle size analyser: beberapa penggunaan instrumen hamburan cahaya. *Seminar Nasional Instrumentasi, Kontrol, Dan Otomasi (SNIKO)*.

Apostolou, M., Assi, S., Fatokun, A. A., & Khan, I. (2021). The Effects of Solid and Liquid Lipids on the Physicochemical Properties of Nanostructured Lipid Carriers. *Journal of Pharmaceutical Sciences*, *110*(8), 2859–2872. https://doi.org/10.1016/j.xphs.2021.04.012

Armstrong, M. J., & Okun, Mi. S. (2020). Diagnosis and Treatment of Parkinson Disease. *JAMA*, *323*(6), 548. https://doi.org/10.1001/jama.2019.22360

Arulkumar, S., & Sabesan, M. (2010a). Biosynthesis and characterization of gold nanoparticle using antiparkinsonian drug Mucuna pruriens plant extract. *International Journal of Research in Pharmaceutical Sciences*, *1*(4), 417–420.

Arulkumar, S., & Sabesan, M. (2010b). Rapid preparation process of antiparkinsonian drug Mucuna pruriens silver nanoparticle by bioreduction and their characterization. *Pharmacognosy Research*, *2*(4), 233–236. https://doi.org/10.4103/0974-8490.69112

Baek, J.-S., Tee, J. K., Pang, Y. Y., Tan, E. Y., Lim, K. L., Ho, H. K., & Loo, S. C. J. (2018). Improved Bioavailability of Levodopa Using Floatable Spray-Coated Microcapsules for the Management of Parkinson's Disease. *NeuroMolecular Medicine*, *20*(0), 262–270. https://doi.org/10.1007/s12017-018-8491-0

Balamurugan K. (2018). Lipid nano particulate drug delivery: An overview of the emerging trend. *The Pharma Innovation Journal*, *7*(7), 779–789. www.thepharmajournal.com

Ball, N., Teo, W. P., Chandra, S., & Chapman, J. (2019). Parkinson's disease and the environment. In *Frontiers in Neurology* (Vol. 10, p. 218). https://doi.org/10.3389/fneur.2019.00218

Beloqui, A., Solinis, M. A., Rodríguez-gascón, A., Almedia, A. J., & Preat, V. (2015). Nanostructured Lipid Carriers: promising drug deliverys system for future clinics. *Nanomedicine: Nanotechnology, Biology, and Medicine*, *12*(1), 14–161. https://doi.org/10.1016/j.nano.2015.09.004

Beloqui, A., Solinís, M. Á., Rodríguez-gascón, A., Almeida, A. J., & Préat, V. (2016). Nanostructured lipid carriers: Promising drug delivery systems for future clinics. *Nanomedicine: Nanotechnology, Biology, and Medicine*, *12*, 143–161.

Berthomieu, C., & Hienerwadel, R. (2009). Fourier transform infrared (FTIR) spectroscopy. *Photosynthesis Research*, *101*(2–3), 157–170. https://doi.org/10.1007/s11120-009-9439-x

Bhosale, A., Paul, G., Mazahir, F., & Yadav, A. K. (2023). Theoretical and applied concepts of nanocarriers for the treatment of Parkinson's diseases. *OpenNano*, *9*(December 2022), 100111. https://doi.org/10.1016/j.onano.2022.100111

Brunetti, A., & Felice, R. Di. (2016). Encyclopedia of Membranes. In *Encyclopedia of Membranes*. https://doi.org/10.1007/978-3-662-44324-8

Costa, C. P., Moreira, J. N., Sousa Lobo, J. M., & Silva, A. C. (2021). Intranasal delivery of nanostructured lipid carriers, solid lipid nanoparticles and nanoemulsions: A current overview of in vivo studies. In *Acta Pharmaceutica Sinica B* (Vol. 11, Issue 4, pp. 925–940). https://doi.org/10.1016/j.apsb.2021.02.012

Dachriyanus. (2004). *Analisis Struktur Senyawa Organik Secara Spektroskopi*. LPITK Universitas Andalas.

Danaei, M., Dehghankhold, M., Ataei, S., Hasanzadeh Davarani, F., Javanmard, R., Dokhani, A., Khorasani, S., & Mozafari, M. (2018). Impact of Particle Size and Polydispersity Index on the Clinical Applications of Lipidic Nanocarrier Systems. *Pharmaceutics*, *10*(2), 57. https://doi.org/10.3390/pharmaceutics10020057

Dhall, R., & Kreitzman, D. L. (2016). Advances in levodopa therapy for Parkinson disease: Review of RYTARY (carbidopa and levedopa) clinical efficacy and safety. *Neurology*, *86*(14), 13–24.

Dhanani, T., Singh, R., Shah, S., Kumari, P., & Kumar, S. (2015). Comparison of green extraction methods with conventional extraction method for extract yield, L-DOPA concentration and antioxidant activity of Mucuna pruriens seed. In *Green Chemistry Letters and Reviews* (Vol. 8, Issue 2, pp. 43–48). Taylor & Francis. https://doi.org/10.1080/17518253.2015.1075070

Doktorovova, S., Souto, E. B., & Silva, A. M. (2014). Nanotoxicology applied to solid lipid nanoparticles and nanostructured lipid carriers – A systematic review of in vitro data. *European Journal of Pharmaceutics and Biopharmaceutics*. https://doi.org/10.1016/j.ejpb.2014.02.005

Dutta, A. (2017). Fourier Transform Infrared Spectroscopy. In *Spectroscopic Methods for Nanomaterials Characterization* (Vol. 2, pp. 73–93). Elsevier Inc. https://doi.org/10.1016/B978-0-323-46140-5.00004-2

Fang, C., Al-suwayeh, S. A., & Fang, J. (2013). Nanostructured Lipid Carriers (NLCs) for Drug Delivery and Targeting. *Recent Patens on Nanotechnology*, *7*(1), 41–55.

Fernandes, F., Dias-Teixeira, M., Delerue-Matos, C., & Grosso, C. (2021). Critical review of lipid-based nanoparticles as carriers of neuroprotective drugs and extracts. *Nanomaterials*, *11*(3), 1–51. https://doi.org/10.3390/nano11030563

George, A., Shah, P. A., & Shrivastav, P. S. (2019). Natural biodegradable polymers based nano-formulations for drug delivery: A review. *International Journal of Pharmaceutics*, *561*(December 2018), 244–264. https://doi.org/10.1016/j.ijpharm.2019.03.011

Ghasemiyeh, P., & Mohammadi-samani, S. (2018). Solid lipid nanoparticles and nanostructured lipid carriers as novel drug delivery systems: applications, advantages and disadvantages. *Research in Pharmaceutical Sciences*, *13*(4), 288–303. https://doi.org/10.4103/1735-5362.235156

Gomes, M. J., Martins, S., Ferreira, D., Segundo, M. A., & Reis, S. (2014). Lipid nanoparticles for topical and transdermal application for alopecia treatment: Development, physicochemical characterization, and in vitro release and penetration studies. *International Journal of Nanomedicine*, *9*(1), 1231–1242. https://doi.org/10.2147/IJN.S45561

Gunawan, G., Dalhar, M., & Kurniawan, S. N. (2017). PARKINSON AND STEM CELL THERAPY. *MNJ (Malang Neurology Journal)*, *3*(1), 39–46. https://doi.org/10.21776/ub.mnj.2017.003.01.7

Gunawan, R. (2022). *NANOENKAPSULASI EKSTRAK KARA BENGUK (Mucuna pruriens) BERBASIS NANOSELULOSA DAN NANOPATI SERTA UJI AKTIVITASNYA SEBAGAI OBAT ANTI-PARKINSON*. Universitas Pendidikan Indonesia.

Habibah, W., Rahayu, T., & Ramadhan, M. (2022). Analisis In Silico dan Kuantitatif Senyawa Metabolit Sekunder Senyawa L-DOPA pada Ekstrak Biji dan Daun Kacang Korong Benguk (Mucuna pruriens D.C.) menggunakan Metode SPektrometri UV-VIS. *Metamorfosa: Journal of Biological Science*, *9*(4), 369–378. https://doi.org/10.24843/metamorfosa.2022.v09.i02.p16

Haider, M., Abdin, S. M., Kamal, L., & Orive, G. (2020). Nanostructured Lipid Carriers for Delivery of Chemotherapeutics: A Review. *Pharmaceutics*, *12*(3), 288. https://doi.org/10.3390/pharmaceutics12030288

Halbig, T. D., & Koller, W. C. (2007). Levodopa. In *Parkinson's Disease* *and Related Disorders, Part II* (Vol. 84, pp. 31–72). Elsevier. https://doi.org/10.1016/S0072-9752(07)84032-2

Hayes, M. T. (2019). Parkinson's Disease and Parkinsonism. In *American Journal of Medicine* (Vol. 132, Issue 7, pp. 802–807). Elsevier Inc. https://doi.org/10.1016/j.amjmed.2019.03.001

Hendradi, E., Rosita, N., & Rahmadhanniar, E. (2017). Effect of Lipid Ratio of Stearic Acid and Oleic Acid on Characteristics of Nanostructure Lipid Carrier (NLC) System of Diethylammonium Diclofenac. *INDONESIAN JOURNAL OF PHARMACY*, *28*(4), 198. https://doi.org/10.14499/indonesianjpharm28iss4pp198

Honary, S., & Zahir, F. (2013). Effect of zeta potential on the properties of nano-drug delivery systems - A review (Part 1). *Tropical Journal of Pharmaceutical Research*, *12*(2), 255–264. https://doi.org/10.4314/tjpr.v12i2.19

Inkson, B. J. (2016). Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) for Materials Characterization. In *Materials Characterization Using Nondestructive Evaluation (NDE) Methods*. Elsevier Ltd. https://doi.org/10.1016/B978-0-08-100040-3.00002-X

Jain, P., Rahi, P., Pandey, V., Asati, S., & Soni, V. (2017). Nanostructure lipid carriers: A modish contrivance to overcome the ultraviolet effects. *Egyptian Journal of Basic and Applied Sciences*, *4*(2), 89–100. https://doi.org/10.1016/j.ejbas.2017.02.001

Jaiswal, P., Gidwani, B., & Vyas, A. (2014). Nanostructured lipid carriers and their current application in targeted drug delivery. *Artificial Cells, Nanomedicine, and Biotechnology*, *44*(1), 27–40. https://doi.org/10.3109/21691401.2014.909822

Jamiati, A. I. (2022). *NANOENKAPSULASI EKSTRAK BIJI KARA BENGUK (Mucuna pruriens) DALAM ASAM PALMITAT SEBAGAI KANDIDAT OBAT ANTIPARKINSON*. Universitas Pendidikan Indonesia.

Jansook, P., Fülöp, Z., & Ritthidej, G. C. (2019). Amphotericin B loaded solid lipid nanoparticles (SLNs) and nanostructured lipid carrier (NLCs): physicochemical and solid-solution state characterizations. *Drug Development and Industrial Pharmacy*, *45*(4), 560–567.

https://doi.org/10.1080/03639045.2019.1569023

Jenning, V., & Gohla, S. (2000). Comparison of wax and glyceride solid lipid nanoparticles (SLN). *International Journal of Pharmaceutics*, *196*, 219–222. https://doi.org/10.1016s0378-5173(99)00426-3

Judefeind, A., & Villiers, M. M. De. (2009). Nanotechnology in Drug Delivery. In M. M. de Villiers, P. Aramwit, & G. S. Kwon (Eds.), *Drug Delivery* (Vol. 100, Issue 2). Springer New York. https://doi.org/10.1007/978-0-387-77667-5

Kannan, M. (2018). Scanning Electron Microscopy: Principle, Components and Applications. In *Textbook on Fundamentals And Applications of Nanotechnology* (pp. 91–90). Tamil Nadu Agricultural University.

Kasture, S., Mohan, M., & Kasture, V. (2013). Mucuna pruriens seeds in treatment of Parkinson' s disease: pharmacological review. *Oriental Pharmacy and Experimental Medicine*, *13*(3), 165–174. https://doi.org/10.1007/s13596-013-0126-2

Katsura, T., & Inui, K. I. (2003). Intestinal Absorption of Drugs Mediated by Drug Transporters: Mechanisms and Regulation. *Drug Metabolism And Pharmacokinetics*, *18*(1), 1–15. https://doi.org/10.2133/dmpk.18.1

Khogta, S., Patel, J., Barve, K., & Londhe, V. (2020). Herbal nano-formulations for topical delivery. *Journal of Herbal Medicine*, *20*(December 2017), 100300. https://doi.org/10.1016/j.hermed.2019.100300

Khosa, A., Reddi, S., & Saha, R. N. (2018). Nanostructured lipid carriers for site-specific drug delivery. *Biomedicine & Pharmacotherapy*, *103*(February), 598–613. https://doi.org/10.1016/j.biopha.2018.04.055

Kim, H. J., Jeon, B. S., & Jenner, P. (2017). Hallmarks of Treatment Aspects: Parkinson's Disease Throughout Centuries Including L-Dopa. In *International Review of Neurobiology* (1st ed., Vol. 132). Elsevier Inc. https://doi.org/10.1016/bs.irn.2017.01.006

Kumari, A., Singla, R., Guliani, A., & Yadav, S. K. (2014). NANOENCAPSULATION FOR DRUG DELIVERY. *EXCLI Journal*, *13*, 265–286.

Lafuente, J. V., Requejo, C., & Ugedo, L. (2019). Nanodelivery of therapeutic agents in Parkinson's disease. *Progress in Brain Research*, *245*, 263–279.

https://doi.org/10.1016/bs.pbr.2019.03.004

Lampariello, L. R., Cortelazzo, A., Guerranti, R., Sticozzi, C., & Valacchi, G. (2012). The Magic Velvet Bean of Mucuna pruriens. *Journal of Traditional and Complementary Medicine*, *2*(4), 331–339. https://doi.org/10.1016/S2225-4110(16)30119-5

Lasoń, E., Sikora, E., & Ogonowski, J. (2013). Influence of process parameters on properties of Nanostructured Lipid Carriers (NLC) formulation. *Acta Biochimica Polonia*, *60*(4), 773–777.

Lopalco, A., & Denora, N. (2018). Nanoformulations for drug delivery: safety, toxicity, and efficacy. *Methods in Molecular Biology*, *1800*, 347–365. https://doi.org/10.1007/978-1-4939-7899-1_17

Madane, R. G., & Mahajan, H. S. (2016). Curcumin-loaded nanostructured lipid carriers (NLCs) for nasal administration: design, characterization, and in vivo study. *Drug Delivery*, *23*(4), 1326–1334. https://doi.org/10.3109/10717544.2014.975382

Malvajerd, S. S., Azadi, A., Zhila, I., Kurd, M., Tahereh, D., Dibaei, M., Zadeh, M. S., Javar, H. A., & Hamidi, M. (2018). Brain Delivery of Curcumin Using Solid Lipid Nanoparticles and Nanostructured Lipid Carriers: Preparation, Optimization, and Pharmacokinetic Evaluation. *ACS Chemical Neuroscience*, *10*, 728–739. https://doi.org/10.1021/acschemneuro.8b00510

Malvern. (2015). A basic guide to particle characterization. *Malvern Whitepaper*, 1–24. https://www.cif.iastate.edu/sites/default/files/uploads/Other_Inst/Particle Size/Particle Characterization Guide.pdf

Martinez-felipe, A., Cook, A. G., Abberley, J. P., Walker, R., Storey, J. M. D., & Imrie, C. T. (2016). An FT-IR spectroscopic study of the role of crystallinity for mixtures containing bipyridines and. *RSC Advances*, *6*, 108164–108179. https://doi.org/10.1039/c6ra17819g

Masoomzadeh, S., Sadighian, S., Gholikhani, T., & Rostamizadeh, K. (2022). Potential use of Nanostructured Lipid Carriers mediated neuronal delivery of Carbamazepine. *Nanomed Res J*, *7*(4), 330–337. https://doi.org/10.22034/nmrj.2022.04.003

Morales, V., McConnell, J., Pérez-Garnes, M., Almendro, N., Sanz, R., & García-Muñoz, R. A. (2021). L-Dopa release from mesoporous silica nanoparticles engineered through the concept of drug-structure-directing agents for Parkinson's disease. *Journal of Materials Chemistry B*, *9*(20), 4178–4189. https://doi.org/10.1039/d1tb00481f

Mozaffar, S., Radi, M., Amiri, S., & McClements, D. J. (2021). A new approach for drying of nanostructured lipid carriers (NLC) by spray-drying and using sodium chloride as the excipient. *Journal of Drug Delivery Science and Technology*, *61*, 102212. https://doi.org/10.1016/j.jddst.2020.102212

Müller, R. H., Alexiev, U., Sinambela, P., & Keck, C. M. (2016). Nanostructured Lipid Carriers (NLC): The Second Generation of Solid Lipid Nanoparticles. In *Percutaneous Penetration Enhancers Chemical Methods in Penetration Enhancement: Nanocarriers* (pp. 161–185). Springer. https://doi.org/10.1007/978-3-662-47862-2

Nand, S., Vivek, R., Payal, K. C., Brijesh, S., & Singh, K. (2020). Mucuna pruriens in Parkinson's and in some other diseases: recent advancement and future prospective. *3 Biotech*, *10*(12), 1–11. https://doi.org/10.1007/s13205-020-02532-7

Neta, F., Da Costa, M., Lima, F., Fernandes, L., Cavalcanti, J., Freire, M., Lucena, E., Do Rego, A., Filho, I., De Azevedo, E., & Guzen, F. (2018). Effects of Mucuna pruriens (L.) Supplementation on Experimental Models of Parkinson's Disease: A Systematic Review. *Pharmacogn Rev*, *12*, 78–84. https://doi.org/10.4103/phrev.phrev

Nguyen, V. H., Thuy, V. N., Van, T. V., Dao, A. H., & Lee, B. J. (2022). Nanostructured lipid carriers and their potential applications for versatile drug delivery via oral administration. *OpenNano*, *8*(August), 100064. https://doi.org/10.1016/j.onano.2022.100064

Opatha, S. A. T., Titapiwatanakun, V., & Chutoprapat, R. (2020). Transfersomes: A Promising Nanoencapsulation Technique for Transdermal Drug Delivery. *Pharmaceutics*, *12*(9), 855. https://doi.org/10.3390/pharmaceutics12090855

Pangestiningsih, T., Susmiati, T., & Wijayanto, H. (2017). Kandungan L-3, 4-dihydroxyphenylalanine Suatu Bahan Neuroprotektif pada Biji Koro Benguk

(Mucuna pruriens) Segar, Rebus, dan Tempe (L-3,4-DIHYDROXYPHENYLALANINE CONTENT AS A NEUROPROTECTIVE MATERIAL ON FRESH, COOKED AND FERMENTED OF KORO BENGUK (MUCUNA PR. *Jurnal Veteriner*, *18*(1), 116–120. https://doi.org/10.19087/jveteriner.2017.18.1.116

Pathania, R., Chawla, P., Khan, H., Kaushik, R., & Azhar, M. (2020). An assessment of potential nutritive and medicinal properties of Mucuna pruriens: a natural food legume. *3 Biotech*, *10*(6), 1–15. https://doi.org/10.1007/s13205-020-02253-x

Paul, A., & Yadav, K. S. (2020). Parkinson's disease: Current drug therapy and unraveling the prospects of nanoparticles. *Journal of Drug Delivery Science and Technology*, *58*. https://doi.org/10.1016/j.jddst.2020.101790

Pavia, D. L., Lampman, G. M., Kriz, G. S., & Vyvyan, J. R. (2009). *INTRODUCTION TO SPECTROSCOPY* (4th ed.). Brooks/Cole, Cengage Learning.

Pezeshki, A., Hamishehkar, H., Ghanbarzadeh, B., Fathollahy, I., Keivani Nahr, F., Khakbaz Heshmati, M., & Mohammadi, M. (2019). Nanostructured lipid carriers as a favorable delivery system for β-carotene. *Food Bioscience*, *27*, 11–17. https://doi.org/10.1016/j.fbio.2018.11.004

Pezzoli, G., & Zini, M. (2010). Levodopa in Parkinson's disease: from the past to the future. *Expert Opin. Pharmacother*, *11*(4), 627–635.

Plaza-Oliver, M., Santander-Ortega, M. J., & Lozano, M. V. (2021). Current approaches in lipid-based nanocarriers for oral drug delivery. *Drug Delivery and Translational Research*, *11*(2), 471–497. https://doi.org/10.1007/s13346-021-00908-7

Poewe, W., Seppi, K., Tanner, C. M., Halliday, G. M., Brundin, P., Volkmann, J., Schrag, A. E., & Lang, A. E. (2017). Parkinson disease. *Nature Reviews Disease Primers*, *3*, 1–21. https://doi.org/10.1038/nrdp.2017.13

Pulikkalpura, H., Kurup, R., Mathew, P. J., & Baby, S. (2015). Levodopa in Mucuna pruriens and its degradation. *Scientific Reports*, *5*(11078). https://doi.org/10.1038/srep11078

Putranti, A. R., Primaharinastiti, R., & Hendradi, E. (2017). EFFECTIVITY AND

PHYSICOCHEMICAL STABILITY OF NANOSTRUCTURED LIPID CARRIER COENZYME Q10 IN DIFFERENT RATIO OF LIPID CETYL PALMITATE AND ALPHA TOCOPHERYL ACETATE AS CARRIER. *Asian Journal of Pharmaceutical and Clinical Research*, *10*(2).

Rahman, H. S., Othman, H. H., Hammadi, N. I., Yeap, S. K., Amin, K. M., Abdul Samad, N., & Alitheen, N. B. (2020). Novel Drug Delivery Systems for Loading of Natural Plant Extracts and Their Biomedical Applications. *International Journal of Nanomedicine*, *Volume 15*, 2439–2483. https://doi.org/10.2147/IJN.S227805

Rahmasari, D., Rosita, N., & Soeratri, W. (2022). Physicochemical Characteristics, Stability, and Irritability of Nanostructured Lipid Carrier System Stabilized with Different Surfactant Ratios. *Jurnal Farmasi Dan Ilmu Kefarmasian Indonesia*, *9*(1), 8–16. https://doi.org/10.20473/jfiki.v9i12022.8-16

Rai, S. N., Birla, H., Zahra, W., Singh, S. Sen, & Singh, S. P. (2017). Immunomodulation of Parkinson's disease using Mucuna pruriens (Mp). In *Journal of Chemical Neuroanatomy* (Vol. 85, pp. 27–35). Elsevier B.V. https://doi.org/10.1016/j.jchemneu.2017.06.005

Rana, A., Karki, N., Tiwari, H., Negi, P. B., & Sahoo, N. G. (2020). ROLE OF NATURAL PRODUCTS IN HERBAL MEDICATION FOR NOVEL DRUG DELIVERY APPLICATION. In G. Tewari, A. Tewari, & L. M. Tewari (Eds.), *Natural Products and Their Utilization Pattern* (pp. 293–319). Nova Science Publisher.

Rao, S. S., Hofmann, L. A., & Shakil, A. (2006). Parkinson's Disease: Diagnosis and Treatment. *American Family Physician*, *74*(12).

Raza, C., Anjum, R., & Shakeel, A. (2019). Parkinson's disease: Mechanisms, translational models and management strategies. *Life Sciences*, *226*(January), 77–90. https://doi.org/10.1016/j.lfs.2019.03.057

Resende, D., Costa Lima, S. A., & Reis, S. (2020). Nanoencapsulation approaches for oral delivery of vitamin A. *Colloids and Surfaces B: Biointerfaces*, *193*(April). https://doi.org/10.1016/j.colsurfb.2020.111121

Rostamabadi, H., Falsafi, S. R., & Jafari, S. M. (2019). Nanoencapsulation of carotenoids within lipid-based nanocarriers. *Journal of Controlled Release*, *298*(February), 38–67. https://doi.org/10.1016/j.jconrel.2019.02.005

Ruktanonchai, U., Limpakdee, S., Meejoo, S., Sakulkhu, U., Bunyapraphatsara, N., Junyaprasert, V., & Puttipipatkhachorn, S. (2008). The effect of cetyl palmitate crystallinity on physical properties of gamma-oryzanol encapsulated in solid lipid nanoparticles. *Nanotechnology*, *19*(9). https://doi.org/10.1088/0957-4484/19/9/095701

Saedi, A., Rostamizadeh, K., Parsa, M., Dalali, N., & Ahmadi, N. (2018). Preparation and Characterization of Nanostructured Lipid Carriers as Drug Delivery System: Influence of Liquid Lipid Types on Loading and Cytotoxicity. *Chemistry and Physics of Lipids*. https://doi.org/10.1016/j.chemphyslip.2018.09.007

Saez, V., Souza, I. D. L., & Mansur, C. R. E. (2018). Lipid nanoparticles (SLN & NLC) for delivery of vitamin E: a comprehensive review. In *International Journal of Cosmetic Science* (Vol. 40, Issue 2, pp. 103–116). https://doi.org/10.1111/ics.12452

Salvi, V. R., & Pawar, P. (2019). Nanostructured lipid carriers (NLC) system: A novel drug targeting carrier. *Journal of Drug Delivery Science and Technology*, *51*(990), 255–267. https://doi.org/10.1016/j.jddst.2019.02.017

Sardjono, R. E., Fauziyah, A. N., Puspitasari, M. D., Musthapa, I., Khoerunnisa, F., Azzahra, G. N., Mamat, R., & Erdiwansyah. (2020). Synthesis and antiparkinsonian activity of nanocomposite of chitosan-tripolyphosphate-Mucuna pruriens L extract (CS-TPP-MP). *IOP Conference Series: Materials Science and Engineering*, *856*(1), 012009. https://doi.org/10.1088/1757-899X/856/1/012009

Sardjono, R. E., Khoerunnisa, F., Musthapa, I., Qowiyah, A., Khairunisa, D., Erfianty, D. D., & Rachmawati, R. (2018). BIOSYNTHESIS, CHARACTERIZATION AND ANTIPARKINSON ACTIVITY OF MAGNETITE-INDONESIAN VELVET BEANS (Mucuna pruriens L.) NANOPARTICLES. *Journal of Engineering Science and Technology*, *13*(12), 4258–4270.

Sardjono, R. E., Khoerunnisa, F., Musthopa, I., Akasum, N. S. M. M., & Rachmawati, R. (2018). Synthesize, characterization, and anti-Parkinson activity of silver-Indonesian velvet beans (Mucuna pruriens) seed extract nanoparticles (AgMPn). *Journal of Physics: Conference Series*, *1013*(1), 012195. https://doi.org/10.1088/1742-6596/1013/1/012195

Sardjono, R. E., Khoerunnisa, F., Musthopa, I., Khairunisa, D., Suganda, P. A., & Rachmawati, R. (2018). Synthesize of zinc nanoparticles using Indonesian velvet bean (Mucuna pruriens) extract and evaluate its potency in lowering catalepsy in mice. *IOP Conference Series: Materials Science and Engineering*, *299*(1), 012080. https://doi.org/10.1088/1757-899X/299/1/012080

Sardjono, R. E., Musthapa, I., Sholihin, H., & Ramdhani, R. F. (2012). PHYSICOCHEMICAL COMPOSITION OF INDONESIAN VELVET BEAN (MUCUNA PRURIENS L.). *Global Jorunal of Research on Medicinal Plants & Indigenous Medicine*, *1*(4), 101–108.

Sartika, R. A. D. (2008). Pengaruh Asam Lemak Jenuh, Tidak Jenuh dan Asam Lemak Trans terhadap Kesehatan. *Kesmas: National Public Health Journal*, *2*(4), 154. https://doi.org/10.21109/kesmas.v2i4.258

Shajari, M., Rostamizadeh, K., Shapouri, R., & Taghavi, L. (2020). Eco-friendly curcumin-loaded nanostructured lipid carrier as an efficient antibacterial for hospital wastewater treatment. *Environmental Technology and Innovation*, *18*, 100703. https://doi.org/10.1016/j.eti.2020.100703

Sharma, A., & Baldi, A. (2018). Nanostructured Lipid Carriers: A Review. *Journal of Developing Drugs*, *7*(1). https://doi.org/10.4172/2329-6631.10001

Shirodkar, R. K., Kumar, L., Mutalik, S., & Lewis, S. (2019). Solid Lipid Nanoparticles and Nanostructured Lipid Carriers: Emerging Lipid Based Drug Delivery Systems. *Pharmaceutical Chemistry Journal*, *53*(5), 440–453. https://doi.org/10.1007/s11094-019-02017-9

Sobczyński, J., & Bielecka, G. (2019). Nanostructure lipid carriers. In *Nanoparticles in Pharmacotherapy* (pp. 275–309). Elsevier. https://doi.org/10.1016/B978-0-12-816504-1.00006-5

Soeratri, W., Hidayah, R., & Rosita, N. (2019). Effect of Combination Soy Bean Oil and Oleic Acid to Characteristic, Penetration, Physical Stability of Nanostructure Lipid Carrier Resveratrol. *Folia Medica Indonesiana*, *55*(3), 213. https://doi.org/10.20473/fmi.v55i3.15505

Subramaniam, B., & Siddik, Z. H. (2020). Optimization of nanostructured lipid carriers: understanding the types, designs, and parameters in the process of formulations. *Journal of Nanoparticle Research*, *22*, 141. https://doi.org/doi.org/10.1007/s11051-020-04848-0

Suryawijaya, A. N., Purwanti, T., Purwanto, D. A., & Soeratri, W. (2022). Characteristic and Physical Stability of Anti-Aging Green Tea Extract (GTE) on NLC with Argan Oil as Liquid Lipid. *Jurnal Farmasi Dan Ilmu Kefarmasian Indonesia*, *9*(2), 115–124. https://doi.org/10.20473/jfiki.v9i22022.115-124

Sveinbjornsdottir, S. (2016). The clinical symptoms of Parkinson's disease. In *Journal of Neurochemistry* (Vol. 139, pp. 318–324). https://doi.org/10.1111/jnc.13691

Tapeinos, C., Battaglini, M., & Ciofani, G. (2017). Advances in the design of solid lipid nanoparticles and nanostructured lipid carriers for targeting brain disease. *Journal of Controlled Release*. https://doi.org/10.1016/j.jconrel.2017.08.033

Teeranachaideekul, V., Souto, E. B., Junyaprasert, V. B., & Müller, R. H. (2007). Cetyl palmitate-based NLC for topical delivery of Coenzyme Q10 - Development, physicochemical characterization and in vitro release studies. *European Journal of Pharmaceutics and Biopharmaceutics*, *67*(1), 141–148. https://doi.org/10.1016/j.ejpb.2007.01.015

Theansungnoen, T., Nitthikan, N., Wilai, M., Chaiwut, P., Kiattisin, K., & Intharuksa, A. (2022). Phytochemical Analysis and Antioxidant, Antimicrobial, and Antiaging Activities of Ethanolic Seed Extracts of Four Mucuna Species. *Cosmetics*, *9*(14). https://doi.org/doi.org/10.3390/cosmetics9010014

Tolosa, E., Garrido, A., Scholz, S. W., & Poewe, W. (2021). Challenges in the diagnosis of Parkinson's disease. In *The Lancet Neurology* (Vol. 20, Issue 5, pp. 385–397). Elsevier Ltd. https://doi.org/10.1016/S1474-4422(21)00030-2

Wahyudi, A., & Rochani, S. (2011). Preliminary Study of Particle Size Measurement of Fine Phosphate Rocks Using Dynamic Light Scattering Method. *Indonesian Mining Journal*, *14*(3), 115–122. http://jurnal.tekmira.esdm.go.id/index.php/imj/article/view/483%0Awww.be ckmancoulter.com,

Waller, D. G., & Sampson, A. P. (2018). Extrapyramidal movement disorders and spasticity. *Medical Pharmacology and Therapeutics*, 325–336. https://doi.org/10.1016/b978-0-7020-7167-6.00024-5

Wirawan, W., Raharjo, S., & Supriyadi. (2022). Formulation and Characteristics of Nanostuctured Lipid Carrier (NLC) Red Palm Oil (RPO) Prepared by High-Pressure Homogenization and Its Applications in Orange Juice. *Indonesian Food and Nutrition Progress*, *19*(1), 31. https://doi.org/10.22146/ifnp.70924

Xia, D., Shrestha, N., van de Streek, J., Mu, H., & Yang, M. (2016). Spray drying of fenofibrate loaded nanostructured lipid carriers. *Asian Journal of Pharmaceutical Sciences*, *11*(4), 507–515. https://doi.org/10.1016/j.ajps.2016.01.001

Yew, H., & Misran, M. (2019). Characterization of fatty acid based nanostructured lipid carrier (NLC) and their sustained release properties. *Progress in Drug Discovery & Biomedical Science*, *2*(1), 1–7.

Yolanda, Y. D., & Nandiyanto, A. B. D. (2021). How to Read and Calculate Diameter Size from Electron Microscopy Images. *ASEAN Journal of Science and Engineering Education*, *2*(1), 11–36. https://doi.org/10.17509/ajsee.v2i1.35203

Yoon, G., Woo, J., & Yoon, P. I. (2013). Solid lipid nanoparticles (SLNs) and nanostructured lipid carriers (NLCs): recent advances in drug delivery. *Journal of Pharmaceutical Investigation*, *43*, 353–362. https://doi.org/10.1007/s40005-013-0087-y