Skip to main content
Advertisement

Log in

Find a journalPublish with usTrack your research
Search
Cart

Nanochitosan Synthesis, Optimization, and Characterization

- Chapter
- First Online: 19 March 2024
- pp 65–112
- Cite this chapter

Nanochitosan-Based Enhancement of Fisheries and Aquaculture

- Patrick Omoregie Isibor

- **46** Accesses

Abstract

The strategic exploration of optimizing nanochitosan for fisheries and aquaculture signifies a comprehensive effort to elevate its effectiveness in tackling the daunting productivity challenges confronting the fisheries sector. Translating laboratory-scale synthesis to large-scale production is a common

hurdle. Maintaining the same properties and performance of nanochitosan at a larger scale requires careful consideration of the production process and conditions. Achieving consistent and reproducible synthesis methods for nanochitosan is also challenging. Variations in raw materials, reaction conditions, and equipment can lead to differences in the properties of the nanochitosan produced.This chapter presents promising optimization strategies that leverage on precise control over synthesis methods, utilizing sophisticated techniques such as acid hydrolysis, ionic gelation, nanoprecipitation, and various advanced approaches. Within these intricate processes, nanochitosan is carefully tailored to manifest specific properties that prove advantageous for diverse applications within aquaculture. Parameters like particle size, stability, and surface modifications are rigorously scrutinized during the optimization process, ensuring that nanochitosan assumes multifaceted functionalities. These functionalities encompass but are not limited to drug delivery mechanisms, prevention of diseases, enhancement of fish feed mixtures, and purification of water resources. The optimization process represents a nuanced understanding of the intricate interrelationship between the properties of nanochitosan and the stringent requirements of aquaculture practices. This depth of comprehension is indispensable for formulating solutions that are not only efficient but also sustainable, thus contributing significantly to the advancement of fisheries and aquaculture practices on a global scale.

This is a preview of subscription content, log in via an institution to check access.

References

- Abbas, Q. (2019). Understanding the UV-vis spectroscopy for nanoparticles. *Journal of Nanomaterials & Molecular Nanotechnology, 8*, 3. https://doi.org/10.4172/2324-8777.1000268

  Article Google Scholar

- Agarwal, N., Nair, M. S., Mazumder, A., & Poluri, K. M. (2018). Chapter 3 – Characterization of nanomaterials using nuclear magnetic resonance spectroscopy. In S. M. Bhagyaraj, O. S. Oluwafemi, N. Kalarikkal, & S. Thomas (Eds.), *Micro and nano technologies, characterization of nanomaterials* (pp. 61–102). Woodhead Publishing. ISBN 9780081019733.

  Chapter Google Scholar

- Bhatia, A., Shard, P., Chopra, D., & Mishra, T. (2011). Chitosan nanoparticles as carrier of immunorestoratory plant extract: Synthesis, characterization and immunorestoratory efficacy. *International Journal of Drug Delivery, 3*, 381–385.

  CAS **Google Scholar**

- Cardoso, V. M., Ferreira, L. M. B., Comparetti, E. J., Sampaio, I., Ferreira, N. N., Miranda, R. R., & Zucolotto, V. (2022). Chapter 4 – Stimuli-responsive polymeric nanoparticles as controlled drug delivery systems. In V. Gajbhiye, K. R. Gajbhiye, & S. Hong (Eds.), *Stimuli-responsive nanocarriers* (pp. 87–117). Academic Press. ISBN 9780128244562.

  Chapter **Google Scholar**

- Chhantyal, P. (2022). *The use of X-ray diffraction for nanoparticle characterization*. The State of Scientific Marketing ’23 Market Report. https://www.azooptics.com/Article.aspx?ArticleID=2180

- Cho, Y., Jun, T. K., & Park, H. J. (2012). Preparation, characterization, and protein loading properties of N-acyl chitosan nanoparticles. *Journal of Applied Polymer Science, 124*, 1366–1371. https://doi.org/10.1002/app.34931

  Article **CAS** **Google Scholar**

- Ding, Y., & Kan, J. (2017). Optimization and characterization of high pressure homogenization produced chemically modified starch nanoparticles. *Journal of Food Science and Technology, 54*(13), 4501–4509. https://doi.org/10.1007/s13197-017-2934-8. Epub 2017 Oct 26. PMID: 29184257; PMCID: PMC5686031.

  Article **CAS** **PubMed** **PubMed Central** **Google Scholar**

- dos Santos, A. M., Carvalho, S. G., Ferreira, L. M. B., Chorilli, M., & Gremião, M. P. D. (2022). Understanding the role of electrostatic interactions on the association of 5-fluorouracil to chitosan-TPP nanoparticles. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 640*, 128417. ISSN 0927-7757.

  Article **Google Scholar**

- Dubey, S., Mody, N., Sharma, R., Agrawal, U., & Vyas, S. P. (2016). Chapter 4 – Nanobiomaterials: Novel nanoplatforms for protein and peptide delivery. In A. M. Grumezescu (Ed.), *Nanobiomaterials in drug delivery* (pp. 111–146). William Andrew Publishing. ISBN 9780323428668.

  Chapter **Google Scholar**

- Eid, M. M. (2022). Characterization of nanoparticles by FTIR and FTIR-microscopy. In *Handbook of consumer nanoproducts*. Springer. https://doi.org/10.1007/978-981-16-8698-6_89

  Chapter **Google Scholar**

- El-Naggar, M. M., Abou-Elmagd, W. S. I., Suloma, A. M., El-Shabaka, H. A., Khalil, M. T., & Abd El-Rahman, F. A. A. (2019). Optimization and physicochemical characterization of chitosan and chitosan nanoparticles extracted from the crayfish Procambarus clarkii wastes. *Journal of Shellfish Research, 38*(2), 385–395. https://doi.org/10.2983/035.038.0220

  Article **Google Scholar**

- El-Naggar, M. M., Haneen, D. S. A., Mehany, A. B. M., & Khalil, M. T. (2020). New synthetic chitosan hybrids bearing some heterocyclic moieties with potential activity as anticancer and apoptosis inducers. *International Journal of Biological Macromolecules, 150*, 1323–1330. https://doi.org/10.1016/j.ijbiomac.2019.10.142

  Article **CAS** **PubMed** **Google Scholar**

- El-Naggar, M. M., Salah, S., El-Shabaka, H. A., Abd El-Rahman, F. A. A., Khalil, M. T., & Suloma, A. (2021). Efficacy of dietary chitosan and chitosan nanoparticles supplementation on health status of Nile tilapia, Oreochromis niloticus (L.). *Aquaculture Reports, 19*, 100628. https://doi.org/10.1016/j.aqrep.2021.100628

  Article **Google Scholar**

- El-Naggar, M. M., Medhat, F., & Taha, A. (2022). Applications of chitosan and chitosan nanoparticles in fish aquaculture. *Egyptian Journal Of Aquatic Biology And Fisheries, 26*(1), 23–43. https://doi.org/10.21608/ejabf.2022.213365

Article **Google Scholar**

- Elsawy, M. A., Saad, G. A., & Sayed, A. M. (2016). Mechanical, thermal, and dielectric properties of poly(lactic acid)/chitosan nanocomposites. *Polymer Engineering and Science, 56*, 987–994. https://doi.org/10.1002/pen.24328

Article **CAS** **Google Scholar**

- El-Sayed, A.-F. M. (2019). *Tilapia culture*. Academic Press. https://doi.org/10.1016/C2017-0-04085-5

Book **Google Scholar**

- Fadlaoui, S., El Asri, O., Mohammed, L., Sihame, A., Omari, A., & Melhaoui, M. (2019). Isolation and characterization of chitin from shells of the freshwater crab Potamon algeriense. *Progress on Chemistry and Application of Chitin and its Derivatives, XXIV*, 23–35. https://doi.org/10.15259/PCACD.24.002

Article **Google Scholar**

- Fatfat, Z., Karam, M., Maatouk, B., Fahs, D., & Gali-Muhtasib, H. (2023). Chapter 7 – Nanoliposomes as safe and efficient drug delivery nanovesicles. In A. K. Nayak, M. S. Hasnain, B. Laha, & S. Maiti (Eds.), *Advanced and modern approaches for drug delivery* (pp. 159–197). Academic Press. ISBN 9780323916684.

Chapter **Google Scholar**

- Ferreira, L. M. B., dos Santos, A. M., Boni, F. I., dos Santos, K. C., Robusti, L. M. G., de Souza, M. P. C., Ferreira, N. N., Carvalho, S. G., Cardoso, V. M. O., Chorilli, M., Cury, B. S. F., de Godoi, D. R. M., & Gremião, M. P. D. (2020). Design of chitosan-based particle systems: A review of the physicochemical foundations for tailored properties. *Carbohydrate Polymers, 250*, 116968. ISSN 0144-8617.

Article **CAS** **PubMed** **Google Scholar**

- Fonseca, L. R., Santos, T. P., Czaikoski, A., & Cunha, R. L. (2020). Modulating properties of polysaccharides nanocomplexes from enzymatic hydrolysis of chitosan. *Food Research International, 137*, 109642. ISSN 0963-9969.

Article **Google Scholar**

- Ghadi, A., Mahjoub, S., Tabandeh, F., & Talebnia, F. (2014). Synthesis and optimization of chitosan nanoparticles: Potential applications in nanomedicine and biomedical engineering. *Caspian Journal of Internal Medicine, 5*(3), 156–161. PMID: 25202443; PMCID: PMC4143737.

  PubMed **PubMed Central** **Google Scholar**

- Ghannam, H., Talab, A. S., Dolganova, N. V., Hussein, A. M. S., & Abdelmaguid, N. M. (2016). Characterization of chitosan extracted from different crustacean shell wastes. *Journal of Applied Sciences, 16*, 454–461.

  Article **CAS** **Google Scholar**

- Gouadec, G., & Colomban, P. (2007). Raman spectroscopy of nanomaterials: How spectra relate to disorder, particle size and mechanical properties. *Progress in Crystal Growth and Characterization of Materials, 53*(1), 1–56. ISSN 0960-8974.

  Article **CAS** **Google Scholar**

- Hao, R., Xing, R., Xu, Z., Hou, Y., Gao, S., & Sun, S. (2010). Synthesis, functionalization, and biomedical applications of multifunctional magnetic nanoparticles. *Advanced Materials, 22*, 2729–2742.

  Article **CAS** **PubMed** **Google Scholar**

- Hejjaji, E. M. A., Smith, A. M., & Morris, G. A. (2018). Evaluation of the mucoadhesive properties of chitosan nanoparticles prepared using different chitosan to tripolyphosphate (CS:TPP) ratios. *International Journal of Biological Macromolecules, 120*, 1610–1617. https://doi.org/10.1016/j.ijbiomac.2018.09.185

  Article **CAS** **PubMed** **Google Scholar**

- Hijazi, N., Le Moigne, N., Rodier, E., Sauceau, M., Vincent, T., Benezet, J. C., & Fages, J. (2019). Biocomposite films based on poly(lactic acid) and chitosan nanoparticles: Elaboration, microstructural and thermal characterization. *Polymer Engineering and Science, 59*, E350–E360. https://doi.org/10.1002/pen.24983

  Article **CAS** **Google Scholar**

- Hu, Y., Jiang, X., Ding, Y., Ge, H., Yuan, Y., & Yang, C. (2002). Synthesis and characterization of chitosan-poly(acrylic acid) nanoparticles. *Biomaterials, 23*, 3193–3201. https://doi.org/10.1016/S0142-9612(02)00071-6

  Article CAS PubMed Google Scholar

- Huang, G., Lu, C., & Yang, H. (2019). Chapter 3 – Magnetic nanomaterials for magnetic bioanalysis. In X. Wang & X. Chen (Eds.), *Micro and nano technologies, novel nanomaterials for biomedical, environmental and energy applications* (pp. 89–109). Elsevier. ISBN 9780128144978.

  Chapter Google Scholar

- Jang, M. K., Kong, B. G., Jeong, Y. I., Lee, C. H., & Nah, J. W. (2004). Physicochemical characterization of α-chitin, β-chitin, and γ-chitin separated from natural resources. *Journal of Polymer Science Part A: Polymer Chemistry, 42*, 3423–3432.

  Article CAS Google Scholar

- Kaya, M., Sargin, I., Tozak, K. O., Baran, T., Erdogan, S., & Sezen, G. (2013). Chitin extraction and characterization from *Daphnia magna* resting eggs. *International Journal of Biological Macromolecules, 61*, 459–464.

  Article CAS PubMed Google Scholar

- Kaya, M., Baran, T., Mentes, A., Asaroglu, M., Sezen, G., & Tozak, J. O. (2014). Extraction and characterization of α-chitin and chitosan from six different aquatic invertebrates. *Food Biophysics, 9*, 145–157.

  Article Google Scholar

- Klapetek, P., Valtr, M., Nečas, D., Salyk, O., & Dzik, P. (2011). Atomic force microscopy analysis of nanoparticles in non-ideal conditions. *Nanoscale Research Letters, 6*, 514. http://www.nanoscalereslett.com/content/6/1/514

  Article PubMed PubMed Central Google Scholar

- Kumar, A., Vimal, A., & Kumar, A. (2016). Why chitosan? From properties to perspective of mucosal drug delivery. *International Journal of Biological Macromolecules, 91*, 615–622.

  Article CAS PubMed Google Scholar

- Lavall, R. L., Assis, O. B. G., & Campana-Filho, S. P. (2007). β-Chitin from the pens of *Loligo* sp.: Extraction and characterization. *Bioresource Technology, 98*, 2465–2472.

  Article CAS PubMed Google Scholar

- Levitin, S. V., Gal'braikh, L. S., Grunin, Y. B., & Masas, D. S. (2014). Supramolecular structure of chitosan acid-hydrolysis products. *Fibre Chemistry, 46*(3), 147–150. https://doi.org/10.1007/s10692-014-9579-4

  Article CAS Google Scholar

- Liu, H., & Gao, C. (2009). Preparation and properties of ionically cross-linked chitosan nanoparticles. *Polymers for Advanced Technologies, 20*, 613–619. https://doi.org/10.1002/pat.1306

  Article CAS Google Scholar

- Loganathan, S., Valapa, R. B., Mishra, R. K., Pugazhenthi, G., & Thomas, S. (2017). Chapter 4 – Thermogravimetric analysis for characterization of nanomaterials. In S. Thomas, R. Thomas, A. K. Zachariah, & R. K. Mishra (Eds.), *Micro and nano technologies, thermal and rheological measurement techniques for nanomaterials characterization* (pp. 67–108). Elsevier. ISBN 9780323461399.

  Google Scholar

- Murakami, Y. & Shimoyama, Y. (2017). Production of nanosuspension functionalized by chitosan using supercritical fluid extraction of emulsion;The Journal of Supercritical Fluids, 128, 121-127, ISSN 0896-8446, https://doi.org/10.1016/j.supflu.2017.05.014.

  Google Scholar

- Nasrollahzadeh, M., Atarod, M., Sajjadi, M., Sajadi, S. M., & Issaabadi, Z. (2019). Chapter 6 – Plant-mediated green synthesis of nanostructures: Mechanisms, characterization, and applications. In M. Nasrollahzadeh, S. Mohammad Sajadi, M. Sajjadi, Z. Issaabadi, & M.

Atarod (Eds.), *Interface science and technology* (Vol. 28, pp. 199–322). Elsevier. ISSN 1573-4285, ISBN 9780128135860.

Google Scholar

- Naveen, N. R., Kurakula, M., & Gowthami, B. (2020). Process optimization by response surface methodology for preparation and evaluation of methotrexate loaded chitosan nanoparticles. *Materials Today: Proceedings, 33*(Part 7), 2716–2724. ISSN 2214-7853.

  Google Scholar

- Ngan, L. T. K., Wang, S. L., Hiep, D. M., Luong, P. M., Vui, N. T., Dinh, T. M., & Dzung, N. A. (2014). Preparation of chitosan nanoparticles by spray drying, and their antibacterial activity. *Research on Chemical Intermediates, 40*, 2165–2175.

  Article CAS Google Scholar

- Ostolska, I., & Wisniewska, M. (2014). Application of the zeta potential measurements to explanation of colloidal Cr_2O_3 stability mechanism in the presence of the ionic polyamino acids. *Colloid & Polymer Science, 292*, 2453–2464.

  Article CAS Google Scholar

- Paulino, A. T., Simionato, J. I., Garcia, A. J., & Nozaki, J. (2006). Characterization of chitosan and chitin produced from silkworm crystalides. *Carbohydrate Polymers, 64*, 98–103.

  Article CAS Google Scholar

- Ramos, A. P. (2017). Dynamic light scattering applied to nanoparticle characterization. In A. L. Da Róz, M. Ferreira, F. de Lima Leite, & O. N. Oliveira (Eds.), *Micro and nano technologies, nanocharacterization techniques* (pp. 99–110). William Andrew Publishing. ISBN 9780323497787.

  Chapter Google Scholar

- Ribeiro, E.F.. São Paulo State University (Unesp), Institute of Biosciences, Humanities and Exact Sciences (Ibilce), Campus São José do Rio Preto, SP, 15054-000, Brazil. *et al*. Chitosan and crosslinked chitosan nanoparticles: Synthesis, characterization and their role as

Pickering
emulsifiers, https://doi.org/10.1016/j.carbpol.2020.116878 (2020).

- Riegger, B. R., Baurer, B., Mirzayeva, A., Tovar, G. E. M., & Bach, M. (2018). Systematic approach for preparation of chitosan nanoparticles via emulsion crosslinking as potential adsorbent in waste-water treatment. *Carbohydrate Polymers, 180*, 46–54.

  Article CAS PubMed Google Scholar

- Rodolfo, C., Eusébio, D., Ventura, C., Nunes, R., Florindo, H. F., Costa, D., & Sousa, Â. (2021). Design of experiments to achieve an efficient chitosan-based DNA vaccine delivery system. *Pharmaceutics, 13*(9), 1369. https://doi.org/10.3390/pharmaceutics13091369. PMID: 34575445; PMCID: PMC8471690.

  Article CAS PubMed PubMed Central Google Scholar

- Roncal, T., Oviedo, A., de Armentia, I. L., Fernández, L., & Villarán, M. C. (2007). High yield production of monomer-free chitosan oligosaccharides by pepsin catalyzed hydrolysis of a high deacetylation degree chitosan. *Carbohydrate Research, 342*(18), 2750–2756. https://doi.org/10.1016/j.carres.2007.08.023

  Article CAS PubMed Google Scholar

- Sakuma, S., Hayashi, M., & Akashi, M. (2011). Design of nanoparticles composed of graft copolymers for oral peptide delivery. *Advanced Drug Delivery Reviews, 47*, 21–37.

  Article Google Scholar

- Shard, P., Bhatia, A., & Sharma, D. (2014). Optimization and physicochemical parameters on synthesis of chitosan nanoparticles by ionic gelation technique. *International Journal of Drug Delivery, 6*, 58–63.

  Google Scholar

- Shi, A. M., Li, D., Wang, L. J., Li, B. Z., & Adhikari, B. (2011). Preparation of starch-based nanoparticles through high-pressure homogenization and miniemulsion cross-linking: Influence of various process parameters on particle size and stability. *Carbohydrate Polymers, 83*, 1604–1610.

Article **CAS** **Google Scholar**

- Shukla, S. K., Mishra, A. K., Arotiba, O. A., & Mamba, B. B. (2013). Chitosan-based nanomaterials: A state-of-the-art review. *International Journal of Biological Macromolecules, 59*, 46–58. https://doi.org/10.1016/j.ijbiomac.2013.04.043

Article **CAS** **PubMed** **Google Scholar**

- Sivashankari, P. R., & Prabaharan, M. (2017). *Deacetylation modification techniques of chitin and chitosan*. Elsevier. https://doi.org/10.1016/B978-0-08-100230-8.00005-4

Book **Google Scholar**

- Sousa, Â., Faria, R., Albuquerque, T., Bhatt, H., Biswas, S., Queiroz, J. A., & Costa, D. (2020). Design of experiments to select triphenylphosphonium-polyplexes with suitable physicochemical properties for mitochondrial gene therapy. *Journal of Molecular Liquids, 302*, 112488. https://doi.org/10.1016/j.molliq.2020.112488

Article **CAS** **Google Scholar**

- Thomasin, C., Merkle, H. P., & Gander, B. A. (1997). Physico-chemical parameters governing protein microencapsulation into biodegradable polyesters by coacervation. *International Journal of Pharmaceutics, 147*(2), 173–186.

Article **CAS** **Google Scholar**

- Vladár, A. E., & Hodoroaba, V. (2020). Chapter 2.1.1 – Characterization of nanoparticles by scanning electron microscopy. In V.-D. Hodoroaba, W. E. S. Unger, & A. G. Shard (Eds.), *Micro and nano technologies, characterization of nanoparticles* (pp. 7–27). Elsevier. ISBN 9780128141823.

Chapter **Google Scholar**

- Wang, Y., & Li, J. (2011). Effects of chitosan nanoparticles on survival, growth and meat quality of tilapia, *Oreochromis nilotica*. *Nanotoxicology, 5*, 425–431.

Article **CAS** **PubMed** **Google Scholar**

- Wang, Y., Chang, Y., Yu, L., Zhang, C., Xu, X., Xue, Y., Li, Z., & Xue, C. (2013). Crystalline structure and thermal property characterization of chitin from Antarctic krill (*Euphausia superba*). *Carbohydrate Polymers, 92*, 90–97.

  Article CAS PubMed Google Scholar

- Wijesena, R. N., Tissera, N., Kannangara, Y. Y., Lin, Y., Amaratunga, G. A. J., & De Silva, K. M. N. (2015). A method for top-down preparation of chitosan nanoparticles and nanofibers. *Carbohydrate Polymers, 117*, 731–738. https://doi.org/10.1016/j.carbpol.2014.10.055

  Article CAS PubMed Google Scholar

- Wong, C. Y., Al-Salami, H., & Dass, C. R. (2020). Formulation and characterisation of insulinloaded chitosan nanoparticles capable of inducing glucose uptake in skeletal muscle cells in vitro. *Journal of Drug Delivery Science and Technology, 57*, 101738. https://doi.org/10.1016/j.jddst.2020.101738

  Article CAS Google Scholar

- Yanat, M., & Schroën, K. (2021). Preparation methods and applications of chitosan nanoparticles; with an outlook toward reinforcement of biodegradable packaging. *Reactive and Functional Polymers, 161*, 104849.

  Article CAS Google Scholar

- Yin, Y., Dang, Q., Liu, C., Yan, J., Cha, D., Yu, Z., Cao, Y., Wang, Y., & Fan, B. (2017). Itaconic acid grafted carboxymethyl chitosan and its nanoparticles: Preparation, characterization and evaluation. *International Journal of Biological Macromolecules, 102*, 10–18. https://doi.org/10.1016/j.ijbiomac.2017.04.005

  Article CAS PubMed Google Scholar

- Zhang, H. L., Wu, S. H., Tao, Y., Zang, L. Q., & Su, Z. Q. (2010). Preparation and characterization of water-soluble chitosan nanoparticles as protein delivery system. *Journal of Nanomaterials, 2010*, 898910.

  Article Google Scholar

- Zhao, D., Yu, S., Sun, B., Gao, S., Guo, S., & Zhao, K. (2018). Biomedical applications of chitosan and its derivative nanoparticles. *Polymer, 10*, 462.

  Article **Google Scholar**

Download references

Author information

Authors and Affiliations

1. **Department of Biological Sciences, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria**
   Patrick Omoregie Isibor

Corresponding author

Correspondence to Patrick Omoregie Isibor .

Editor information

Editors and Affiliations

1. **Department of Biological Sciences, College of Science and Technology, Covenant University, Ota, Nigeria**
   Patrick Omoregie Isibor
2. **Zoology, University of Ibadan, Ibadan, Nigeria**
   Aina Olukukola Adeogun
3. **Environmental Management and Toxicology, University of Benin, Benin City, Nigeria**
   Alex Ajeh Enuneku

Rights and permissions

Reprints and permissions

Copyright information

© 2024 The Author(s), under exclusive license to Springer Nature Switzerland AG

About this chapter

Cite this chapter

Isibor, P.O. (2024). Nanochitosan Synthesis, Optimization, and Characterization. In: Isibor, P.O., Adeogun, A.O., Enuneku, A.A. (eds) Nanochitosan-Based Enhancement of Fisheries and Aquaculture. Springer, Cham. https://doi.org/10.1007/978-3-031-52261-1_3

Download citation

- .RIS
- .ENW
- .BIB

- DOIhttps://doi.org/10.1007/978-3-031-52261-1_3
- Published19 March 2024
- Publisher NameSpringer, Cham
- Print ISBN978-3-031-52260-4
- Online ISBN978-3-031-52261-1
- eBook PackagesChemistry and Materials ScienceChemistry and Material Science (R0)

Publish with us

Policies and ethics

Access this chapter

Log in via an institution

Chapter

EUR 29.95
Price includes VAT (Nigeria)

- Available as PDF
- Read on any device
- Instant download
- Own it forever

Buy Chapter

eBook

EUR 117.69

Hardcover Book

EUR 149.99

Tax calculation will be finalised at checkout

Purchases are for personal use only

Institutional subscriptions

- Sections
- References

- Abstract
- References
- Author information
- Editor information
- Rights and permissions
- Copyright information
- About this chapter
- Publish with us

Discover content

- Journals A-Z
- Books A-Z

Publish with us

- Publish your research
- Open access publishing

Products and services

- Our products
- Librarians
- Societies
- Partners and advertisers

Our imprints

- Springer

- Nature Portfolio
- BMC
- Palgrave Macmillan
- Apress
- Your privacy choices/Manage cookies
- Your US state privacy rights
- Accessibility statement
- Terms and conditions
- Privacy policy
- Help and support
- Cancel contracts here

165.73.223.224

Covenant University Ota (3006481499)

© 2024 Springer Nature