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A Review on the Development of Microcarriers for Cell Culture Applications

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Abstract

Microcarrier-based cell culture systems have gained significant attention and popularity in tissue engineering and regenerative medicine. In this culture system, tissue cells are grown as a monolayer on the surface of small solid particles called microcarriers (100 to 300 μm), kept suspended in the culture medium by stirring. This technology has paved the way for creating engineered tissues, one of the cutting-edge topics in tissue engineering and regenerative medicine. Microcarrier-based approaches have been proposed for three-dimensional (3D) cell culture in which cellular morphology and functions are maintained in vivo. This paper provides an overview of the optimal characteristics such as microcarriers' size, shape, density and porosity. Various methods of preparation of

microcarriers and surface modification techniques have been elaborated. Recent advances and applications of microcarriers in biotechnology fields, like the production of viral vaccines and recombinant proteins, culture and expansion of stem cells (SC), are described. © Universiti Putra Malaysia Press.

Author keywords

Biomolecule immobilization; microcarrier; polymer; preparation; surface modification

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References (83)

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All

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1 Arifin, M.A., Mel, M., Swan, S.Y., Samsudin, N., Hashim, Y.Z.H.-Y., Salleh, H.M.

Optimization of ultraviolet/ozone (UVO_3) process conditions for the preparation of gelatin coated polystyrene (PS) microcarriers

(2022) *Preparative Biochemistry and Biotechnology*, 52 (2), pp. 181-196.
www.tandf.co.uk/journals/titles/10826068.asp
doi: 10.1080/10826068.2021.1923031

View at Publisher

2 Azahar, N.I., Mokhtar, N.M., Mahmood, S., Aziz, M.A.A., Arifin, M.A.

EVALUATION OF PIPER BETLE L. EXTRACTS AND ITS ANTIVIRULENCE ACTIVITY TOWARDS P. AERUGINOSA

(2023) *Jurnal Teknologi*, 85 (1), pp. 133-140. Cited 2 times.
https://journals.utm.my/jurnalteknologi/issue/view/498
doi: 10.11113/jurnalteknologi.v85.18892

View at Publisher

3 Badenes, S.M., Fernandes-Platzgummer, A., Rodrigues, C.A.V., Diogo, M.M., Da Silva, C.L., Cabral, J.M.S.

Microcarrier Culture Systems for Stem Cell Manufacturing

(2016) *Stem Cell Manufacturing*, pp. 77-104. Cited 18 times.
http://www.sciencedirect.com.ezlib.iium.edu.my/science/book/9780444632654
ISBN: 978-044463265-4
doi: 10.1016/B978-0-444-63265-4.00004-2

View at Publisher

4 Burnett, M.J.B., Burnett, A.C.

Therapeutic recombinant protein production in plants: Challenges and opportunities

(2020) *Plants People Planet*, 2 (2), pp. 121-132. Cited 139 times.
nph.onlinelibrary.wiley.com/journal/25722611
doi: 10.1002/ppp3.10073

View at Publisher

5 Campos, E., Branquinho, J., Carreira, A.S., Carvalho, A., Coimbra, P., Ferreira, P., Gil, M.H.

Designing polymeric microparticles for biomedical and industrial applications

(2013) *European Polymer Journal*, 49 (8), pp. 2005-2021. Cited 161 times.
doi: 10.1016/j.eurpolymj.2013.04.033

View at Publisher

6 Cer, E., Gürpinar, Ö.A., Onur, M.A., Tuncel, A.

Polyethylene glycol-based cationically charged hydrogel beads as a new microcarrier for cell culture

(2007) *Journal of Biomedical Materials Research - Part B Applied Biomaterials*, 80 (2), pp. 406-414. Cited 16 times.
doi: 10.1002/jbm.b.30611

View at Publisher

7 Chen, A.K.L., Reuveny, S., Oh, S.K.W.

Application of human mesenchymal and pluripotent stem cell microcarrier cultures in cellular therapy: Achievements and future direction

(2013) *Biotechnology Advances*, 31 (7), pp. 1032-1046. Cited 242 times.
doi: 10.1016/j.biotechadv.2013.03.006

View at Publisher

8 Chen, X.-Y., Chen, J.-Y., Tong, X.-M., Mei, J.-G., Chen, Y.-F., Mou, X.-Z.

Recent advances in the use of microcarriers for cell cultures and their ex vivo and in vivo applications

(2020) *Biotechnology Letters*, 42 (1). Cited 65 times.
www.wkap.nl/journalhome.htm/0141-5492
doi: 10.1007/s10529-019-02738-7

View at Publisher

9 Chevalot, I., Visvikis, A., Nabet, P., Engasser, J.-M., Marc, A.

Production of a membrane-bound proteins, the human gamma-glutamyl transferase, by CHO cells cultivated on microcarriers, in aggregates and in suspension

(1994) *Cytotechnology*, 16 (2), pp. 121-129. Cited 13 times.
doi: 10.1007/BF00754614

View at Publisher

10 Chia, M.-Y., Chung, W.-Y., Wang, C.-H., Chang, W.-H., Lee, M.-S.

Development of a high-growth enterovirus 71 vaccine candidate inducing cross-reactive neutralizing antibody responses

(2018) *Vaccine*, 36 (9), pp. 1167-1173. Cited 9 times.
www.elsevier.com/locate/vaccine
doi: 10.1016/j.vaccine.2018.01.041

View at Publisher

11 Le Clainche, T., Moisan, A., Coll, J.-L., Martel-Frachet, V.

The disc-shaped microcarriers: A new tool for increasing harvesting of adipose-derived mesenchymal stromal cells

(2021) *Biochemical Engineering Journal*, 174, art. no. 108082. Cited 4 times.
www.elsevier.com/locate/bej
doi: 10.1016/j.bej.2021.108082

View at Publisher

12 Clapp, K.P., Castan, A., Lindskog, E.K.

Upstream Processing Equipment

(2018) *Biopharmaceutical Processing: Development, Design, and Implementation of Manufacturing Processes*, pp. 457-476. Cited 22 times.
http://www.sciencedirect.com.ezlib.iium.edu.my/science/book/9780081006238
ISBN: 978-012812552-6; 978-008100623-8
doi: 10.1016/B978-0-08-100623-8.00024-4

View at Publisher

13 Clara-Trujillo, S., Marín-Payá, J.C., Cordón, L., Sempere, A., Gallego Ferrer, G., Gómez Ribelles, J.L.

Biomimetic microspheres for 3D mesenchymal stem cell culture and characterization

(2019) *Colloids and Surfaces B: Biointerfaces*, 177, pp. 68-76. Cited 23 times.
www.elsevier.com/locate/colsurfb
doi: 10.1016/j.colsurfb.2019.01.050

View at Publisher

14 Croughan, M.S., Hamel, J.P., Wang, D.I.C.

Effects of microcarrier concentration in animal cell culture

(1988) *Biotechnology and Bioengineering*, 32 (8), pp. 975-982. Cited 86 times.
doi: 10.1002/bit.260320805

View at Publisher

15 Dashtimoghadam, E., Fahimipour, F., Tongas, N., Tayebi, L.

Microfluidic fabrication of microcarriers with sequential delivery of VEGF and BMP-2 for bone regeneration (Open Access)

(2020) *Scientific Reports*, 10 (1), art. no. 11764. Cited 41 times.
www.nature.com/srep/index.html
doi: 10.1038/s41598-020-68221-w

View at Publisher

16 Ding, S.-L., Liu, X., Zhao, X.-Y., Wang, K.-T., Xiong, W., Gao, Z.-L., Sun, C.-Y., (...), Zhang, M.-Z.

Microcarriers in application for cartilage tissue engineering: Recent progress and challenges

(2022) *Bioactive Materials*, 17, pp. 81-108. Cited 56 times.
http://www.keaipublishing.com/en/journals/bioactive-materials/
doi: 10.1016/j.bioactmat.2022.01.033

View at Publisher

17 Eisenkraetzer, D.

Upstream and downstream process technology: Bioreactors for animal cell culture

(2014) *Animal Cell Biotechnology: In Biologics Production*, pp. 389-521. Cited 2 times.
http://www.degruyter.com/view/books/9783110278965/9783110278965.fm/9783110278965.fm.xml?format=EBOK
ISBN: 978-311027896-5; 978-311027886-6
doi: 10.1515/9783110278965.389

View at Publisher

18 Fliedl, L., Kaisermayer, C.

Scalable transient gene expression in adherent mammalian cells using polyethylenimine

(2014) *Methods in Molecular Biology*, 1104, pp. 29-34.
http://www.springer.com.ezlib.iium.edu.my/series/7651
ISBN: 978-162703732-7
doi: 10.1007/978-1-62703-733-4_3

View at Publisher

19 Frey, S.J., Hoffman, A.S., Hubbell, J.A., Kane, R.S.

Surface-Immobilized Biomolecules (Open Access)

(2020) *Biomaterials Science: An Introduction to Materials in Medicine*, pp. 539-551. Cited 7 times.
https://www-sciencedirect-com.ezlib.iium.edu.my/book/9780128161371
ISBN: 978-012816137-1; 978-012816138-8
doi: 10.1016/B978-0-12-816137-1.00036-2

View at Publisher

20 Goodwin, T.J., McCarthy, M., Cohrs, R.J., Kaufer, B.B.

3D tissue-like assemblies: A novel approach to investigate virus-cell interactions (Open Access)

(2015) *Methods*, 90, pp. 76-84. Cited 19 times.
http://www.elsevier.com.ezlib.iium.edu.my/inca/publications/store/6/2/2/9/1/4/index.htt
doi: 10.1016/j.ymeth.2015.05.010

View at Publisher

21 Govindarajan, T., Shandas, R.

A survey of surface modification techniques for next-generation shape memory polymer stent devices

(2014) *Polymers*, 6 (9), pp. 2309-2331. Cited 78 times.
http://www.mdpi.com/2073-4360/6/9/2309/pdf
doi: 10.3390/polym6092309

View at Publisher

22 Gümüşderelioglu, M., Çakmak, S., Timuçin, H.O., Çakmak, A.S.

Thermosensitive PHEMA microcarriers: ATRP synthesis, characterization, and usabilities in cell cultures

(2013) *Journal of Biomaterials Science, Polymer Edition*, 24 (18), pp. 2110-2125. Cited 21 times.
doi: 10.1080/09205063.2013.827104

View at Publisher

23 Guo, J., Li, K., Ning, C., Liu, X.

Improved cellular bioactivity by heparin immobilization on polycarbonate film via an aminolysis modification for potential tendon repair

(2020) *International Journal of Biological Macromolecules*, 142, pp. 835-845. Cited 11 times.
www.elsevier.com/locate/ijbiomac
doi: 10.1016/j.ijbiomac.2019.09.136

View at Publisher

24 Heathman, T.R.J., Nienow, A.W., Rafiq, Q.A., Coopman, K., Kara, B., Hewitt, C.J.

Agitation and aeration of stirred-bioreactors for the microcarrier culture of human mesenchymal stem cells and potential implications for large-scale bioprocess development

(2018) *Biochemical Engineering Journal*, 136, pp. 9-17. Cited 28 times.
www.elsevier.com/locate/bej
doi: 10.1016/j.bej.2018.04.011

View at Publisher

25 Holmes, C., Tabrizian, M.

Surface Functionalization of Biomaterials (Open Access)

(2015) *Stem Cell Biology and Tissue Engineering in Dental Sciences*, pp. 187-206. Cited 25 times.
http://www.sciencedirect.com.ezlib.iium.edu.my/science/book/9780123971579
ISBN: 978-012397778-6; 978-012397157-9
doi: 10.1016/B978-0-12-397157-9.00016-3

View at Publisher

26 Hossain, K.M.Z., Patel, U., Ahmed, I.

Development of microspheres for biomedical applications: A review

(2015) *Progress in Biomaterials*, 4 (1), pp. 1-19. Cited 176 times.
www.springer.com/journal/40204
doi: 10.1007/s40204-014-0033-8

View at Publisher

27 Huang, L., Abdalla, A.M.E., Xiao, L., Yang, G.

Biopolymer-based microcarriers for three-dimensional cell culture and engineered tissue formation (Open Access)

(2020) *International Journal of Molecular Sciences*, 21 (5), art. no. 1895. Cited 76 times.
https://www.mdpi.com/1422-0067/21/5/1895/pdf
doi: 10.3390/ijms21051895

View at Publisher

28 Huang, L., Xiao, L., Jung Poudel, A., Li, J., Zhou, P., Gauthier, M., Liu, H., (...), Yang, G.

Porous chitosan microspheres as microcarriers for 3D cell culture

(2018) *Carbohydrate Polymers*, 202, pp. 611-620. Cited 83 times.
http://www.elsevier.com.ezlib.iium.edu.my/wps/find/journaldescription.cws_home/405871/description#description
doi: 10.1016/j.carbpol.2018.09.021

View at Publisher

29 Ismail, N.A., Abd Aziz, M.A., Hisyam, A., Abidin, M.A.

Separation of samarium from medium rare earth mixture using multi-stage counter-current extraction

(2021) *Chemical Engineering Communications*, 208 (5), pp. 764-774. Cited 12 times.
www.tandf.co.uk/journals/titles/00986445.asp
doi: 10.1080/00986445.2020.1746654

View at Publisher

30 Kankala, R.K., Zhao, J., Liu, C.-G., Song, X.-J., Yang, D.-Y., Zhu, K., Wang, S.-B., (...), Chen, A.-Z.

Highly Porous Microcarriers for Minimally Invasive In Situ Skeletal Muscle Cell Delivery

(2019) *Small*, 15 (25), art. no. 1901397. Cited 123 times.
http://onlinelibrary.wiley.com.ezlib.iium.edu.my/journal/10.1002/(ISSN)1613-6829
doi: 10.1002/smll.201901397

View at Publisher

31 Kiesslich, S., Vila-Chã Losa, J.P., Gélinas, J.-F., Kamen, A.A.

Serum-free production of rVSV-ZEBOV in Vero cells: Microcarrier bioreactor versus scale-X™ hydro fixed-bed

(2020) *Journal of Biotechnology*, 310, pp. 32-39. Cited 30 times.
www.elsevier.com/locate/jbiotec
doi: 10.1016/j.jbiotec.2020.01.015

View at Publisher

32 Kuang, P., Constant, K.
Increased wettability and surface free energy of polyurethane by ultraviolet ozone treatment
(2015) *Wetting and Wettability*, pp. 85-102. Cited 24 times.
M. Aliofkhazraei (Ed), InTech
https://doi-org.ezlib.iium.edu.my/10.5772/60798

33 Kumar, A., Starly, B.

Large scale industrialized cell expansion: Producing the critical raw material for biofabrication processes (Open Access)

(2015) *Biofabrication*, 7 (4), art. no. 044103. Cited 58 times.
http://iopscience.iop.org/article/10.1088/1758-5090/7/4/044103/pdf
doi: 10.1088/1758-5090/7/4/044103

View at Publisher

34 Lagreca, E., Onesto, V., Di Natale, C., La Manna, S., Netti, P.A., Vecchione, R.

Recent advances in the formulation of PLGA microparticles for controlled drug delivery (Open Access)

(2020) *Progress in Biomaterials*, 9 (4), pp. 153-174. Cited 166 times.
www.springer.com/journal/40204
doi: 10.1007/s40204-020-00139-y

View at Publisher

35 Lai, J.-Y., Ma, D.H.-K.

Ocular biocompatibility of gelatin microcarriers functionalized with oxidized hyaluronic acid

(2017) *Materials Science and Engineering C*, 72, pp. 150-159. Cited 28 times.
doi: 10.1016/j.msec.2016.11.067

View at Publisher

36 Laput, O.A., Vasenina, I.V., Shapovalova, Y.G., Ochered'ko, A.N., Chernyavskii, A.V., Kudryashov, S.V., Kurzina, I.A.

Low-Temperature Barrier Discharge Plasma Modification of Scaffolds Based on Polylactic Acid (Open Access)

(2022) *ACS Applied Materials and Interfaces*, 14 (37), pp. 41742-41750. Cited 6 times.
http://pubs.acs.org.ezlib.iium.edu.my/journal/aamick
doi: 10.1021/acsami.2c11027

View at Publisher

37 Levato, R., Planell, J.A., Mateos-Timoneda, M.A., Engel, E.

Role of ECM/peptide coatings on SDF-1α triggered mesenchymal stromal cell migration from microcarriers for cell therapy

(2015) *Acta Biomaterialia*, 18, pp. 59-67. Cited 41 times.
http://www.journals.elsevier.com/acta-biomaterialia
doi: 10.1016/j.actbio.2015.02.008

View at Publisher

38 Li, J., Lam, A.T.-L., Toh, J.P.W., Reuveny, S., Oh, S.K.-W., Birch, W.R.

Tunable Volumetric Density and Porous Structure of Spherical Poly-ϵ-caprolactone Microcarriers, as Applied in Human Mesenchymal Stem Cell Expansion (Open Access)

(2017) *Langmuir*, 33 (12), pp. 3068-3079. Cited 25 times.
http://pubs.acs.org.ezlib.iium.edu.my/journal/langd5
doi: 10.1021/acs.langmuir.7b00125

View at Publisher

39 Luo, X., Niu, Y., Fu, X., Lin, Q., Liang, H., Liu, L., Li, N.

Large-scale microcarrier culture of chinese perch brain cell for viral vaccine production in a stirred bioreactor

(2021) *Vaccines*, 9 (9), art. no. 1003. Cited 8 times.
https://www.mdpi.com/2076-393X/9/9/1003/pdf
doi: 10.3390/vaccines9091003

View at Publisher

40 Ma, Z., Gao, C., Ji, J., Shen, J.

Protein immobilization on the surface of poly-L-lactic acid films for improvement of cellular interactions

(2002) *European Polymer Journal*, 38 (11), pp. 2279-2284. Cited 105 times.
doi: 10.1016/S0014-3057(02)00119-2

View at Publisher

41 Maillot, C., De Isla, N., Loubiere, C., Toye, D., Olmos, E.

Impact of microcarrier concentration on mesenchymal stem cell growth and death: Experiments and modeling

(2022) *Biotechnology and Bioengineering*, 119 (12), pp. 3537-3548. Cited 6 times.
http://onlinelibrary.wiley.com.ezlib.iium.edu.my/journal/10.1002/(ISSN)1097-0290
doi: 10.1002/bit.28228

View at Publisher

42 Tanaka, A., Fukui, S.

Immobilized Organelles (Open Access)

(2018) *Immobilized Cells and Organelles: Volume I*, pp. 101-120. Cited 2 times.
http://www.tandfebooks.com/doi/book/10.1201/9781351073394
ISBN: 978-135108184-9; 978-131589429-4
doi: 10.1201/9781351073394

View at Publisher

43 Mattos, D.A., Silva, M.V., Gaspar, L.P., Castilho, L.R.

Increasing Vero viable cell densities for yellow fever virus production in stirred-tank bioreactors using serum-free medium

(2015) *Vaccine*, 33 (35), pp. 4288-4291. Cited 17 times.
www.elsevier.com/locate/vaccine
doi: 10.1016/j.vaccine.2015.04.050

View at Publisher

44 May, C. P.
(2016) *The study and fabrication of a novel thermally responsive microcarrier for cell culture application*
[Unpublish doctoral thesis]. University of Nottingham, England

45 Meiser, I., Majer, J., Katsen-Globa, A., Schulz, A., Schmidt, K., Stracke, F., Koutsouraki, E., (...), Zimmermann, H.

Droplet-based vitrification of adherent human induced pluripotent stem cells on alginate microcarrier influenced by adhesion time and matrix elasticity

(2021) *Cryobiology*, 103, pp. 57-69. Cited 8 times.
http://www.elsevier.com.ezlib.iium.edu.my/inca/publications/store/6/2/2/8/1/4/index.htt
doi: 10.1016/j.cryobiol.2021.09.010

View at Publisher

46 Merten, O.-W.

Advances in cell culture: Anchorage dependence (Open Access)

(2015) *Philosophical Transactions of the Royal Society B: Biological Sciences*, 370 (1661), art. no. 20140040. Cited 124 times.
http://rstb.royalsocietypublishing.org/content/royptb/370/1661/20140040.full.pdf
doi: 10.1098/rstb.2014.0040

View at Publisher

47 Minati, L., Migliaresi, C., Lunelli, L., Viero, G., Dalla Serra, M., Speranza, G.

Plasma assisted surface treatments of biomaterials (Open Access)

(2017) *Biophysical Chemistry*, 229, pp. 151-164. Cited 46 times.
www.elsevier.com/locate/bpc
doi: 10.1016/j.bpc.2017.07.003

View at Publisher

48 Mohamad, N.R., Marzuki, N.H.C., Buang, N.A., Huyop, F., Wahab, R.A.

An overview of technologies for immobilization of enzymes and surface analysis techniques for immobilized enzymes (Open Access)

(2015) *Biotechnology and Biotechnological Equipment*, 29 (2), pp. 205-220. Cited 1122 times.
http://www-tandfonline-com.ezlib.iium.edu.my/doi/pdf/10.1080/13102818.2015.1008192
doi: 10.1080/13102818.2015.1008192

View at Publisher

49 Mozaffari, A., Gashti, M.P., Mirjalili, M., Parsania, M.

Argon and argon-oxygen plasma surface modification of gelatin nanofibers for tissue engineering applications

(2021) *Membranes*, 11 (1), art. no. 31, pp. 1-13. Cited 45 times.
https://www.mdpi.com/2077-0375/11/1/31
doi: 10.3390/membranes11010031

View at Publisher

50 Nikolova, M.P., Chavali, M.S.

Recent advances in biomaterials for 3D scaffolds: A review (Open Access)

(2019) *Bioactive Materials*, 4, pp. 271-292. Cited 703 times.
http://www.keaipublishing.com/en/journals/bioactive-materials/
doi: 10.1016/j.bioactmat.2019.10.005

View at Publisher

51 Mehdizadeh Omrani, M., Kumar, H., Mohamed, M.G.A., Golovin, K., S. Milani, A., Hadjizadeh, A., Kim, K.

Polyether ether ketone surface modification with plasma and gelatin for enhancing cell attachment

(2021) *Journal of Biomedical Materials Research - Part B Applied Biomaterials*, 109 (5), pp. 622-629. Cited 26 times.
http://onlinelibrary.wiley.com.ezlib.iium.edu.my/journal/10.1002/(ISSN)1552-4965
doi: 10.1002/jbm.b.34726

View at Publisher

52 Ornelas-González, A., González-González, M., Rito-Palomares, M.

Microcarrier-based stem cell bioprocessing: GMP-grade culture challenges and future trends for regenerative medicine (Open Access)

(2021) *Critical Reviews in Biotechnology*, 41 (7), pp. 1081-1095. Cited 21 times.
http://www-tandfonline-com.ezlib.iium.edu.my/loi/ibty20
doi: 10.1080/07388551.2021.1898328

View at Publisher

53 Özçam, A.E., Efimenko, K., Genzer, J.

Effect of ultraviolet/ozone treatment on the surface and bulk properties of poly(dimethyl siloxane) and poly(vinylmethyl siloxane) networks

(2014) *Polymer*, 55 (14), pp. 3107-3119. Cited 70 times.
http://www.journals.elsevier.com/polymer/
doi: 10.1016/j.polymer.2014.05.027

View at Publisher

54 Park, Y., Chen, Y., Ordovas, L., Verfaillie, C.M.

Hepatic differentiation of human embryonic stem cells on microcarriers

(2014) *Journal of Biotechnology*, 174 (1), pp. 39-48. Cited 49 times.
www.elsevier.com/locate/jbiotec
doi: 10.1016/j.jbiotec.2014.01.025

View at Publisher

55 Pörtner, R.
Bioreactors for mammalian cells
(2015) *Animal Cell Culture*, pp. 89-135. Cited 20 times.
M. Al-Rubeai (Ed), –). Springer
https://doi-org.ezlib.iium.edu.my/10.1007/978-3-319-10320-4_4

56 Rafiq, Q.A., Ruck, S., Hanga, M.P., Heathman, T.R.J., Coopman, K., Nienow, A.W., Williams, D.J., (...), Hewitt, C.J.

Qualitative and quantitative demonstration of bead-to-bead transfer with bone marrow-derived human mesenchymal stem cells on microcarriers: Utilising the phenomenon to improve culture performance (Open Access)

(2018) *Biochemical Engineering Journal*, 135, pp. 11-21. Cited 41 times.
www.elsevier.com/locate/bej
doi: 10.1016/j.bej.2017.11.005

View at Publisher

57 Ravikumar, M.N.V.

Handbook of polyester drug delivery systems (Open Access)

(2016) *Handbook of Polyester Drug Delivery Systems*, pp. 1-717. Cited 3 times.
http://www.panstanford.com/books/9789814669665
ISBN: 978-981466966-5; 978-981466965-8
doi: 10.4032/9789814669665

View at Publisher

58 Recek, N., Resnik, M., Motaln, H., Lah-Turnšek, T., Augustine, R., Kalarikkal, N., Thomas, S., (...), Mozetič, M.

Cell Adhesion on Polycaprolactone Modified by Plasma Treatment

(2016) *International Journal of Polymer Science*, 2016, art. no. 7354396. Cited 74 times.
http://www.hindawi.com/journals/ijps/
doi: 10.1155/2016/7354396

View at Publisher

59 Reddy, M.S.B., Ponnamma, D., Choudhary, R., Sadasivuni, K.K.

A comparative review of natural and synthetic biopolymer composite scaffolds (Open Access)

(2021) *Polymers*, 13 (7), art. no. 1105. Cited 604 times.
https://www.mdpi.com/2073-4360/13/7/1105/pdf
doi: 10.3390/polym13071105

View at Publisher

60 Samsudin, N., Hashim, Y.Z.H.-Y., Arifin, M.A., Salleh, H.M.

Surface modification of microcporous of polycaprolactone (PCL) microcarrier to improve microcarrier biocompatibility (Open Access)

(2018) *International Journal on Advanced Science, Engineering and Information Technology*, 8 (4-2), pp. 1642-1647.
ijaseit.insightsociety.org
doi: 10.18517/ijaseit.8.4-2.7060

View at Publisher

61 Saralidze, K., Koole, L.H., Knetsch, M.L.W.

Polymeric microspheres for medical applications

(2010) *Materials*, 3 (6), pp. 3537-3564. Cited 147 times.
http://www.mdpi.com/1996-1944/3/6/3537/pdf
doi: 10.3390/ma3063537

View at Publisher

62 Sengupta, P., Prasad, B.L.V.

Surface Modification of Polymers for Tissue Engineering Applications: Arginine Acts as a Sticky Protein Equivalent for Viable Cell Accommodation (Open Access)

(2018) *ACS Omega*, 3 (4), pp. 4242-4251. Cited 26 times.
pubs.acs.org/journal/acsodf
doi: 10.1021/acsomega.8b00215

View at Publisher

63 Hushmand Shahrifi, B., Mohammadi, M., Manoochehri, M., Atashi, A.

Mechanical and biological properties of polycaprolactone/fibrin nanocomposite adhesive produced by electrospinning method (Open Access)

(2020) *Bulletin of Materials Science*, 43 (1), art. no. 135. Cited 13 times.
http://www.ias.ac.in/matersci/
doi: 10.1007/s12034-020-02111-9

View at Publisher

64 Shi, X., Cui, L., Sun, H., Jiang, N., Heng, L., Zhuang, X., Gan, Z., (...), Chen, X.

Promoting cell growth on porous PLA microspheres through simple degradation methods

(2019) *Polymer Degradation and Stability*, 161, pp. 319-325. Cited 23 times.
doi: 10.1016/j.polymdegradstab.2019.01.003

View at Publisher

65 Shirokaze, J., Yanagida, K., Shudo, K., Konomoto, K., Kamiya, K., Sagara, K.
IL-4 production using macroporous microcarrier
(1995) *Animal Cell Technology: Developments Towards the 21st Century*, pp. 877-881.
E. C. Beuvery, J. B. Griffiths & W. P. Zeijlemaker (Eds), –). Springer
https://doi-org.ezlib.iium.edu.my/10.1007/978-94-011-0437-1_141

66 Sia, Y. S., Azahar, N. I., Aziz, M. A. A., Arifin, M. A.
Sequential adaptation to Serum-free medium for Vero cells cultivation on ultraviolet/ozone (UVO) treated microcarrier
(2023) *Materials Today: Proceedings*. Cited 3 times.
https://doi-org.ezlib.iium.edu.my/10.1016/j.matpr.2023.08.031

67 Silva, A. C., Roldão, A., Teixeira, A., Fernandes, P., Sousa, M. F., Alves, P. M.
Cell immobilization for the production of viral vaccines
(2015) *Animal Cell Engineering*, pp. 541-563. Cited 3 times.
M. Al-Rubeai (Ed), –). Springer
https://doi-org.ezlib.iium.edu.my/10.1007/978-3-319-10320-4_17

68 Silva, C. L. D., Carmelo, J. G., Fernandes-Platzgummer, A., Weber, J. L., Bear, M., Hervy, M., Diogo, M. M., (...), Cabral, J. S.
Scalable production of human mesenchymal stem/stromal cells in microcarrier-based culture systems
(2014) *Cytotherapy*, 16 (4), pp. S101-S102. Cited 2 times.
https://doi-org.ezlib.iium.edu.my/10.1016/j.jcyt.2014.01.377

69 Suzuki, H., Kasai, K., Kimura, Y., Miyata, S.

UV/ozone surface modification combined with atmospheric pressure plasma irradiation for cell culture plastics to improve pluripotent stem cell culture

(2021) *Materials Science and Engineering C*, 123, art. no. 112012. Cited 10 times.
https://www.journals.elsevier.com/materials-science-and-engineering-c
doi: 10.1016/j.msec.2021.112012

View at Publisher

70 Syromotina, D.S., Surmenev, R.A., Surmeneva, M.A., Boyandin, A.N., Epple, M., Ulbricht, M., Oehr, C., (...), Volova, T.G.

Oxygen and ammonia plasma treatment of poly(3-hydroxybutyrate) films for controlled surface zeta potential and improved cell compatibility (Open Access)

(2016) *Materials Letters*, 163, pp. 277-280. Cited 9 times.
http://www.journals.elsevier.com/materials-letters/
doi: 10.1016/j.matlet.2015.10.080

View at Publisher

71 Tavassoli, H., Alhosseini, S.N., Tay, A., Chan, P.P.Y., Weng Oh, S.K., Warkiani, M.E.

Large-scale production of stem cells utilizing microcarriers: A biomaterials engineering perspective from academic research to commercialized products (Open Access)

(2018) *Biomaterials*, 181, pp. 333-346. Cited 129 times.
http://www.journals.elsevier.com/biomaterials/
doi: 10.1016/j.biomaterials.2018.07.016

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72 Tham, C.Y., Hamid, Z.A.A., Ahmad, Z., Ismail, H.

Surface engineered poly (lactic acid) (PLA) microspheres by chemical treatment for drug delivery system (Open Access)

(2014) *Key Engineering Materials*, 594-595, pp. 214-218. Cited 32 times.
https://www.scientific.net/KEM
ISBN: 978-303785937-7
doi: 10.4028/www.scientific.net/KEM.594-595.214

View at Publisher

73 Tharmalingam, T., Sunley, K., Spearman, M., Butler, M.

Enhanced production of human recombinant proteins from CHO cells grown to high densities in macroporous microcarriers (Open Access)

(2011) *Molecular Biotechnology*, 49 (3), pp. 263-276. Cited 25 times.
doi: 10.1007/s12033-011-9401-y

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74 Thompson, M., Giuffre, A., McClenny, C., Van Dyke, M.

A keratin-based microparticle for cell delivery

(2021) *Journal of Biomaterials Applications*, 35 (6), pp. 579-591. Cited 9 times.
http://jba.sagepub.com.ezlib.iium.edu.my/
doi: 10.1177/0885328220951892

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75 Trabelsi, K., Ben Zakour, M., Kallel, H.

Purification of rabies virus produced in Vero cells grown in serum free medium

(2019) *Vaccine*, 37 (47), pp. 7052-7060. Cited 23 times.
www.elsevier.com/locate/vaccine
doi: 10.1016/j.vaccine.2019.06.072

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76 Tsai, A.-C., Jeske, J., Chen, X., Yuan, X., Li, Y.

Influence of Microenvironment on Mesenchymal Stem Cell Therapeutic Potency: From Planar Culture to Microcarriers

(2020) *Frontiers in Bioengineering and Biotechnology*, 8, art. no. 640. Cited 64 times.
http://journal.frontiersin.org/journal/bioengineering-and-biotechnology#archive
doi: 10.3389/fbioe.2020.00640

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77 Verma, A., Verma, M., Singh, A.

Animal tissue culture principles and applications (Open Access)

(2020) *Animal Biotechnology: Models in Discovery and Translation*, pp. 269-293. Cited 88 times.
https://www-elsevier-com.ezlib.iium.edu.my/books/animal-biotechnology/verma/978-0-12-811710-1
ISBN: 978-012811710-1
doi: 10.1016/B978-0-12-811710-1.00012-4

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78 Van Wezel, A.L.

Growth of cell-strains and primary cells on micro-carriers in homogeneous culture [17]

(1967) *Nature*, 216 (5110), pp. 64-65. Cited 532 times.
doi: 10.1038/216064a0

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79 Wieland, F., Bruch, R., Bergmann, M., Partel, S., Urban, G.A., Dincer, C.

Enhanced protein immobilization on polymers-A plasma surface activation study (Open Access)

(2020) *Polymers*, 12 (1), art. no. 104. Cited 34 times.
https://res.mdpi.com/d_attachment/polymers/polymers-12-00104/article_deploy/polymers-12-00104.pdf
doi: 10.3390/POLYM12010104

View at Publisher

80 Yang, L., Zhang, J., He, J., Zhang, J., Gan, Z.

Fabrication, hydrolysis and cell cultivation of microspheres from cellulose-graft-poly(l-lactide) copolymers (Open Access)

(2016) *RSC Advances*, 6 (21), pp. 17617-17623. Cited 19 times.
http://pubs.rsc.org/en/journals/journalissues
doi: 10.1039/c5ra25993b

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