E-ISSN: 2320-1215
P-ISSN: 2322-0112

Research and Reviews: Journal of Pharmacy and Pharmaceutical Sciences

Green Nanotechnology

Abha Verma[1,2] Megha Sharma[1], and Swati Tyagi[1*]

[1]Department of Biotechnology, Meerut Institute of Engineering and Technology, Meerut, Uttar Pradesh, India
[2]IFTM University Moradabad, Uttar Pradesh, India

Review Article

Received: 16/12/2016
Revised: 26/12/2016
Accepted: 30/12/2016

***For Correspondence**

Swati Tyagi, Department of Biotechnology, Meerut Institute of Engineering and Technology, Meerut, Uttar Pradesh, India

E-mail: swatityagi99@gmail.com

Keywords:
Phytochemical, Environment, Green chemistry, Healthcare, Nanoproducts, plants

ABSTRACT

Nanotechnology covers a unique phenomenon that enables novel applications in different fields. Nanotechnology promises a sustainable future by its growth in green chemistry to develop Green Nanotechnology. Green nanotechnology means the application of green chemistry and green engineering principles in field of nanotechnology to manipulate the molecules within a nanoscale range. This review reflects how nanotechnology can be advantages as a green alternative in different aspects of nanoparticle synthesis.

INTRODUCTION

Nanotechnology is an interdisciplinary field of science that demands to manage, produce and develop novel opportunity to use science, engineering and new approaches with nanoscale invention to support human and environment health[1]. Nanotechnology is a popular subject of scientific interest that deals with the manipulation of individual molecules at a supramolecular range of 100 nanometers. Nanotechnology R&D reflects the improvement in design and application of materials, devices & models that exhibits new sustainable future. Thus, the recognition of such types of applications of nanotechnology[1-7] led to the development of the “green nanoscience”.

Green nanotechnology grounds on field of Green Chemistry that reflects the main aim of nanotechnology to create eco-friendly nano-objects[8-15] to reduce human health and environmental hazards[16-20] by application of green nano-products. Green nanotechnology simply refers to field of nanotechnology to enhance the environmental sustainability[17] and to maintain eco-friendly environment.

Green nanoparticles synthesized from the different green nanotechnological approaches consist of a well- defined chemical composition, size and applications in many technological fields. Green nanoparticles developed through

E-ISSN: 2320-1215
P-ISSN: 2322-0112

eco-friendly techniques have considerable importance in areas of medical biology, industrial microbiology, environmental microbiology, bioremediation, clean technology and electronics[21-34].

Globally the innovative approaches can be spread through a group of peoples forming societies to acknowledge the research of green and chemical methods for sustainability in field of engineering & medical biology[24,29]. Such societies offer a platform to gain qualifications and try for new opportunity that can publishes scholarly editions. One such type of societies is Nano paprika, which is the International nano science community that is open for all researchers, professors including students with the main focus on Nano networks applications. Other than Nano paprika, European Biotechnology Thematic Network Association also reflects the same way of association of researchers around the globe to encourage the research and nano-networks[35,36].

NANOPARTICLE SYNTHESIS BY GREEN ROUTE

Nanotechnology uses key methods to generate new products and to enhance the properties of broad range of market products of electronics, packaging, healthcare and coatings[37-42]. This use of nanotechnology is enhanced by Green nanotechnology. There are two methods for the synthesis of nanoparticles, one includes Chemical synthesis[43,44] and other focused on Green synthesis. The importance of nanotechnology in research field emphasis on the synthesis of nanoparticles with different chemical compositions, sizes, morphologies and controlled dispersities[45-50]. The nanoparticle synthesized through the chemical methods involve Chemical reduction[51-60] using different metals and chemicals such as sodium citrate, ascorbate, sodium borohydride, etc. Whereas in Green way for the synthesis of nanoparticle green reducing agents[61-64] are employed using phytochemical[65] extracts of different natural products such as leaf extract, juice extract, extract from medicinal plants[66-70] etc. to provide unlimited opportunities for new discoveries.

The chemical method involves toxic solvents[71,72], high pressure, energy and high temperature for the preparation of nanoparticles[73-75]. Green synthesis involves the synthesis of nanoparticles through aqueous extract of green product (such as plant extract of *Musa balbisiana* (banana), *Azadirachta indica* (neem) and *Ocimum tenuiflorum* (black tulsi), etc.) and metal ions[76-83] (such as sliver ions). The fixed ratio of plant extract and silver ions were mixed and kept at room temperature for reduction the change in color was noticed at regular intervals of time from yellow to reddish brown or dark brown that confirmed the formation of nanoparticles. Further, the synthesized nanoparticles were characterized by using UV, XRD and FTIR data[84-89].

Development and achievement in field of Green nanotechnology can be much explained by recent published work of scientists, researchers and professors. An open access journal provides visibility and accessibility to the readers about the innovative research in various fields of nanotechnology. The Nanomaterials & Molecular Nanotechnology reflects many research work of Green nanotechnology to encourage the ongoing research in nanotechnology. The journal of Organic Chemistry: Current Research also reflects the present and most sited organic research for nanotechnology.

Nowadays, the more focus is to develop an eco-friendly processes, to reduce the toxic chemicals in the process of nanoparticles synthesis. This marks the development in field of green chemistry to eco-friendly procedures for the synthesis and congregation of metal NPs. Green synthesis approaches include mixed-valence polyoxometalates, polysaccharides, tollens because plant extract termed as phytochemical are rich in phenolic compounds, alkaloids, diterpenoid, steroid and other compounds which inhibit the development of various microorganisms as phytochemicals[90-92] act as reducing and capping agent in the reduction of metal ions to metal nanoparticles[93-95].

CHALLENGES IN GREEN SYNTHESIS

Green nanotechnology has been making great forward progress, but the growth of nanoproducts and NPs is challenged by different processes of commercialization as green synthesis requires Improvements in specific characterization, development of design and use of green NPs. There is a further ongoing need for research in development and nanomaterial synthesis routes. Thus, to explain such need researchers focused to present a concept among all through conferences. Green Chemistry and Green Energy, on August 24-26, 2017 at Beijing, China give special importance for green resources to make an eco-friendly environment with more productivity and market value. Along with the challenges and issues associated with green nanotechnology, we can't diminish or reduce this new sustainable approach.

In Nanomaterials & Molecular Nanotechnology, authors emphasis on the environmental nano-science research by explaining that there is a need to develop engineered nanomaterials[93-96] for environment and other applications. International Conference on Nanotechnology 2017 organized on August 7-8, 2017 at Beijing, China also going to reflect new approaches in nanotechnology developed in recent years and new aspect for coming years with an aim to spread the green technology. The conference explains the processes of Nanofabrication[97] in a nanometers range.

NEW APPROACHES IN GREEN NANOTECHNOLOGY

Green nanotechnology heightens the environmental sustainability[98-101] by enhancement in use of green nano-products because such products offer benefits over the chemically synthesised nano-products. The green nano-products are those that provide solutions to environmental challenges involving direct or indirect application at nanoscale. These nano-products are lightweight nanocomposites[102].

The Green nanoparticles synthesised via green chemical principle provides important applications to prevent waste, synthesised less hazardous chemical, renewable feedstock, reduce derivatives. Green nanotechnology not completely fits into the picture of sustainability whereas there is a need to go beyond environmental protection for sustainability. Green synthesised nanomaterials could help to alleviate major sustainability issues of climate change, renewable energy, natural resources[103-107] and toxic products.

David A Schiraldi completed his PhD in Chemistry, explains in one of its conference 3rd International Conference on Past and Present Research Systems of Green Chemistry organised in Nevada, USA about the Green chemistry. According to Dr. Schiraldi a material that comes from nature is truly green explaining about the synthetic polymers. Similarly according to Shaker Mousa, nanotechnology is growing its approach in scientific and medical communities by potential application in aspects of cancer[108], other disorders and new nano-carrier systems[109].

Nanotechnology has grown its importance in research field of medical chemistry. Thus, the involvement of green method of nanoparticle synthesis reports the easiest, efficient, and eco-friendly in comparison to chemical-mediated or microbe mediated synthesis.

CONCLUSION

Nanotechnology has a revolutionary effect on many fields of science, techniques and industry. The current development in field of nanotechnology has harnessed the power to convert phytochemicals into nanoparticles via green chemistry as this will mitigate nanotechnology's impact on sustainability of the environment. The development in nanotechnology concerns in environmental approach is growing at a larger extend to save fules, reduce materials for production, toxic effects medical care, monitor environment pollutants and green manufacture.

REFERENCES

1. Verma A and Tyagi S. Biological Synthesis of Silver Nanoparticles. Research & Reviews: Journal of Pharmaceutics and Nanotechnology. 2016;4:1-5.
2. Tyagi S. Nanoparticles – An Overview of Classification and Applications. Research & Reviews: Journal of Pharmaceutics and Nanotechnology. 2016;4:102-108.
3. Pandey KV and Tyagi S. Pharmaceutical Nanotechnology: A Rising Tide of Challenge & Opportunities. Research & Reviews: Journal of Pharmaceutics and Nanotechnology. 2016;4:S2.
4. Pandey KV and Tyagi S. Nanoparticles: An Overview of Preparation. Research & Reviews: Journal of Pharmaceutics and Nanotechnology. 2016;4:S2.

5. Pandey KV and Tyagi S. Pharmaceutical Nanotechnology: A Rising Tide of Challenge & Opportunities. Research & Reviews: Journal of Pharmaceutics and Nanotechnology. 2016;4:S2.
6. Kreuter J. Nanoparticles In: Kreuter J (ed) Colloidal drug delivery systems. Marcel Dekker Inc, New York. 1994;219–342.
7. Couvreur P. Polyalkylcyanoacrylates as colloidal drug carriers. Crit Rev Ther Drug Carr Syst. 1988;5:1–20.
8. Kumaresh S. Biodegradable polymeric nanoparticles as drug delivery devices. J Control Release. 2001;70:1–20.
9. Mohanraj VJ and Y Chen. Nanoparticles – A Review. Trop J Pharm Res. 5;561-573.
10. Hadziioannou G and Malliaras GG. Semiconducting polymers. Wiley-VCH Publisher, Weinheim. 2000.
11. Couvreur P and Vauthier C. Nanotechnology: intelligent design to treat complex disease. Pharm Res. 2006;23:1417–1450.
12. Pinto Reis C, et al. Nanoencapsulation I Methods for preparation of drug-loaded polymeric nanoparticles. Nanomed Nanotechnol Biol Med. 2006;2: 8–21.
13. Pinto Reis C, et al. Nanoencapsulation II. Biomedical applications and current status of peptide and protein nanoparticulate delivery systems. Nanomed Nanotechnol Biol Med. 2006;2:53–65.
14. Rao JP and Geckeler KE. Polymer nanoparticles: preparation techniques and size-control parameters. Prog Polym Sci. 2011;36:887–913.
15. Pecher J and Mecking S. Nanoparticles of conjugated polymers. Chem Rev. 2010;110:6260–6279.
16. Anton N, et al. Design and production of nanoparticles formulated from nano-emulsion templates–A review. J Controlled Release. 2008;128:185–199.
17. Vauthier C and Bouchemal K. Methods for the preparation and manufacture of polymeric nanoparticles. Pharm Res. 200926:1025–1058.
18. Landfester K, et al. From polymeric particles to multifunctional nanocapsules for biomedical applications using the miniemulsion process. J Polym Sci A Polym Chem. 2010;48:493–515.
19. Allemann E, et al. Drug-loaded nanoparticles—Preparation methods and drug targeting issues. Eur J Pharm Biopharm. 1993;39:173–191.
20. Quintanar-Guerrero D, et al. Preparation techniques and mechanisms of formation of biodegradable nanoparticles from preformed polymers. Drug Dev Ind Pharm. 1998;24:1113–1128.
21. De Jaeghere F, et al. Nanoparticles, In: Mathiowitz E (ed) Encyclopedia of controlled drug delivery, vol 2. Wiley-VCH, New York. 1999;641–664.
22. Couvreur P, et al. Nanocapsule technology: a review. Crit Rev Ther Drug. 2001;19:99–134.
23. Tuncel D and Demir HV. Conjugated polymer nanoparticles. Nanoscale. 2010;2:484–494.
24. Gangopadhyay R. Conducting Polymer Nanostructures, In: Nalwa H S (ed) Encyclopedia of nanoscience and nanotechnology. American Scientific Publishers, Stevenson Ranch. 2004;2:105–131.
25. Wallace GG and Innis PC. Inherently conducting polymer nanostructures. J Nanosci Nanotechnol. 2002;2:441–451.
26. Koushik OS, et al. Nano Drug Delivery Systems to Overcome Cancer Drug Resistance - A Review. J Nanomed Nanotechnol. 2016;7: 378.
27. Salager JL. Pharmaceutical emulsions and suspensions, formulation concepts for the emulsion maker. Marcel Dekker Inc, New York. 2000;19–72.
28. Hwi Jin Ko. Recent Update of Nanobiosensors Using Olfactory Sensing Elements and Nanomaterials. Biosens J. 2015;4:129.
29. Zaman H. Addressing Solubility through Nano Based Drug Delivery Systems. J Nanomed Nanotechnol. 2016;7:376.
30. Kashif Maroof, et al. Scope of Nanotechnology in Drug Delivery. J Bioequiv Availab. 2016.
31. Shi J, et al. Nanotechnology in drug delivery and tissue engineering: From discovery to applications. Nano. Lett. 2010;10:3223–3230.
32. Mironov V, et al. Nanotechnology in vascular tissue engineering: from nanoscaffolding towards rapid vessel biofabrication. Trends Biotechnol. 2008;26:338–344.
33. Suprava Pate, et al. Nanotechnology in Healthcare: Applications and Challenges. Med Chem. 2015;5:528.

34. The Royal Society and The Royal Academy of Engineering. Nanoscience and nanotechnologies: opportunities and uncertainties. London, UK:2004.
35. Luis E Trujillo, et al. Nanotechnology Applications for Food and Bioprocessing Industries. Biol Med. 2015;8:289.
36. Kim BS. et al. Nanolayer: Delivering Multiple Therapeutics from Hierarchically Assembled Surface Coatings. Langmuir. 2009;25:14086–14092.
37. Tasleem Arif, et al. Therapeutic and Diagnostic Applications of Nanotechnology in Dermatology and Cosmetics. J Nanomedine Biotherapeutic Discov. 2015;5:134.
38. Jiji Abraham, et al. Carbon Nanotube-thermally Reduced Graphene Hybrid/Styrene Butadiene Rubber Nano Composites: Mechanical, Morphological and Dielectric Studies. 2015;4: 3.
39. Iijima S. Helical microtubules of graphitic carbon. Nature. 1991;354:56–58.
40. Kreuter J. Nanoparticles. In: Kreuter J, editor. Colloidal Drug Delivery Systems. M. Dekker; New York. 1994;219–342.
41. Moghimi SM, et al. Long-circulating and target-specific nanoparticles: theory to practice. Pharmacol Rev. 2001;53:283–318.
42. Panyam J, et al. Solid-state solubility influences encapsulation and release of hydrophobic drugs from PLGA/PLA nanoparticles. J Pharm Sci. 2004;93:1804–1814.
43. Panyam J, et al. Solid-state solubility influences encapsulation and release of hydrophobic drugs from PLGA/PLA nanoparticles. J Pharm Sci. 2004;93:1804–1814.
44. Ramsay, DA. Intensities and shapes of infrared absorption bands of substances in the liquid phase. J Am Chem Soc. 1952;74:72–80.
45. Asane, G. et al. Polymers for mucoadhesive drug delivery system: a current status. Drug Dev. Ind. Pharm. 2008;34:1246–1266.
46. Alaqad K and Saleh TA. Gold and Silver Nanoparticles: Synthesis Methods, Characterization Routes and Applications towards Drugs. J Environ Anal Toxicol. 2016;6:384.
47. Vicky VM, et al. Introduction to metallic nanoparticles. J Pharm Bioallied Sci. 2010;2:282–289.
48. Tawfik AS. Nanomaterials for Pharmaceuticals Determination. Bioenergetics. 2016.
49. Robert JH et al. Low-Dimensional Nanoparticle Clustering in Polymer Micelles and Their Transverse Relaxivity Rates. ACS Nano. 2013;7:5824–5833.
50. Sreeraj G, et al. Effective Drug Delivery System of Biopolymers Based On Nanomaterials and Hydrogels - A Review. Drug Des. 2016;5:2.
51. Carlos RA, et al. Reliable Tools for Quantifying the Morphogical Properties at the Nanoscale. Biol Med. 2016;8:281.
52. Alivisatos P. The use of nanocrystals in biological detection. Nat. Biotechnol. 2004;22:47–52.
53. Kong J, et al. Nanotube molecular wires as chemical sensors. Science. 2000;287:622–625.
54. Kong J and Dai H. Full and modulated chemical grating of individual carbon nanotubes by organic amine compounds. J. Phys. Chem. 2001;105:2890–2893.
55. Cui Y, et al.. Nanowire nanosensors for highly sensitive and Selective detection of biological and chemical species. Science. 2001;293:1289–1292.
56. Tolani SB, et al. Towards biosensors based on conducting polymer nanowires. Anal. Bioanal. Chem. 2009;393:1225–1231.
57. Wang ZL. Characterizing the structure and properties of individual wire-like nanoentities. Adv Mater. 2000;12:1295.
58. Duan X, et al. Indium phosphide nanowires as building blocks for nanoscale electronic and optoelectronic devices. Nature. 2001;409:66.
59. Cui Y and Lieber CM. Functional nanoscale electronic devices assembled using silicon nanowire building blocks. Science. 2001;291:851.
60. Huang Y, et al. Logic gates and computation from assembled nanowire building blocks. Science. 2001;294:1313.
61. Xia Y, et al. One-dimensional nanostructures: synthesis, characterization, and applications. Adv Mater. 2003;15:353.
62. Jibowu T. The Formation of Doxorubicin Loaded Targeted Nanoparticles using Nanoprecipitation, Double Emulsion and Single Emulsion for Cancer Treatment. J Nanomed Nanotechnol. 2016;7:379.

63. Novoselov KS, et al. Electric field effect in atomically thin carbon films. Science. 2004;306:666–669.
64. Winkin N, et al. Nanomaterial-modified Flexible Micro-electrode Array by Electrophoretic Deposition of Carbon Nanotubes. Biochip Tissue Chip. 2016;6:115.
65. Zhao Q, et al. Electrochemical sensors based on carbon nanotubes. Electroanalysis. 2002;14:1609–1613.
66. Weaver CL, et al. Electrically controlled drug delivery from graphene oxide nanocomposite films. ACS nano. 2014;8:1834–1843.
67. Lone B. Adsorption of Cytosineon Single-walled Carbon Nanotubes. J Nanomed Nanotechnol. 2016;7:354.
68. Soleimani H, et al. Synthesis of Carbon Nanotubes for Oil-water Interfacial Tension Reduction. Oil Gas Res. 2015;1:104.
69. Dumsile W Nyembe, et al. Effects of Ingested Multi-Walled Carbon Nanotubes in Poecilia reticulata: Localization and Physiological Responses. J Environ Anal Toxicol. 2016;6:368.
70. Soto K, et al. Cytotoxic effects of aggregated nanomaterials. Acta Biomater. 2007;3:351–358.
71. Sreelakshmy V, et al. Green Synthesis of Silver Nanoparticles from Glycyrrhiza glabra Root Extract for the Treatment of Gastric Ulcer. J Dev Drugs. 2016;5:152.
72. Sindhwani S, et al. Three-Dimensional Optical Mapping of Nanoparticle Distribution in Intact Tissues. Science Advances. 2016;1:10.
73. Sameh SA. Carboxyfullerenes: Nanomolecules that Work. J Nanomedine Biotherapeutic Discov. 2012;2:e110.
74. Valter B and Claudio N. Fabrication of Supports for Carbon Fullerenes Hard Disk Unit. J Nanomed Nanotechnol. 2014;5:230.0
75. Kepley C. Fullerenes in Medicine; Will it ever Occur. J Nanomed Nanotechnol. 2012;3:e111.
76. Kazue M, et al. Antimicrobial Photodynamic Therapy with Functionalized Fullerenes: Quantitative Structure-activity Relationships. J Nanomed Nanotechnol. 2011;2:109.
77. Imtiyaz RP and Athar AH. Dendrimers as an Efficient Catalyst for the Oxidation of Multi Substituted Alcohols. J Fertil Pestic. 2016;7:160.
78. Khalid A and Tawfik AS. Gold and Silver Nanoparticles: Synthesis Methods, Characterization Routes and Applications towards Drugs. J Environ Anal Toxicol. 2016;6:384.
79. Liron L, et al. Ultrasound-Mediated Surface Engineering of Theranostic Magnetic Nanoparticles: An Effective One-Pot Functionalization Process Using Mixed Polymers for siRNA Delivery. J Nanomed Nanotechnol. 2016;7:385.
80. Mohammad N and Hossein M. Polymeric Nanostructures as Colloidal Drug Delivery Systems: Thermosensitive Hydrogels Containing Self-Assembled Micelles. J Nanomed Nanotechnol. 2015;6:301.
81. Lee CC, et al. A single dose of doxorubicin-functionalized bow-tie dendrimer cures mice bearing C-26 colon carcinomas. Proc Natl Acad Sci. 2006;103:16649–16654.
82. Vashist SK. Dendrimers: Prospects for Bioanalytical Sciences. J Nanomed Nanotechnol. 2013;4:e131.
83. Ahmed AH. Targeting of Somatostatin Receptors using Quantum Dots Nanoparticles Decorated with Octreotide. J Nanomedic Nanotechnol. 2015;S6-005.
84. Demir E. Genotoxicology of Quantum Dots Used in Medical and Pharmaceutical Sciences. Hereditary Genet. 2015;4:151.
85. Nikalje AP. Nanotechnology and its Applications in Medicine. Med chem. 2015;5:081-089.
86. Ingale AG et al. Chaudhari AN. Biogenic Synthesis of Nanoparticles and Potential Applications: An Eco-Friendly Approach. J Nanomed Nanotechol. 2013;4:165.
87. Ghashghaei S and Emtiazi G. Production of Hydroxyapatite Nanoparticles Using Tricalcium-Phosphate by Alkanindiges illinoisensis. J Nanomater Mol Nanotechnol. 2013;2:5.
88. Hartung GA and Mansoori GA. In vivo General Trends, Filtration and Toxicity of Nanoparticles. J Nanomater Mol Nanotechnol. 2013;2:3.
89. Brigger I, et al. Nanoparticles in cancer therapy and diagnosis. Adv Drug Deliv Rev. 2012;64:24–36.
90. Salager JL. Microemulsions, handbook of detergents—part A: properties. Marcel Dekker Inc. 1999;253–302.

E-ISSN: 2320-1215
P-ISSN: 2322-0112

91. Muhammad SN, et al. Design and Fabrication of Biomass Extruder of 50 mm Diameter Briquette Size. Innov Ener Res. 2015;5:128.
92. Stejskal J. Colloidal dispersions of conducting polymers. J Polym Mater. 2001;18:225–258
93. Vincent B. Electrically conducting polymer colloids and composites. Polym Adv Technol. 1995;6:356–361.
94. Armes SP. Electrically conducting polymer colloids. Polym News. 1995;20:233–237.
95. Aldissi M and Armes SP. Colloidal dispersions of conducting polymers. Prog Org Coat. 1991;19:21–58.
96. Armes SP and Vincent B. Post-doping of sterically-stabilized polyacetylene latexes. Synth Met 1988;25:171–179.
97. Groenendaal L, et al. Poly(3,4-ethylenedioxythiophene) and its derivatives: past, present, and future. Adv Mater. 2000;12:481–494.
98. Huyal IO, et al. Quantum efficiency enhancement in film by making nanoparticles of polyfluorene. Opt Express. 12008;6:13391–13397.
99. Ozel IO, et al. Non-radiative resonance energy transfer in bi-polymer nanoparticles of fluorescent conjugated polymers. Opt Express. 2010;18:670–684.
100. Grigalevicius S, et al. Excitation energy transfer from semi-conducting polymer nanoparticles to surface-bound fluorescent dyes. Macromol Rapid Commun. 2006;27:200–202.
101. Pecher J and Mecking S. Nanoparticles from step-growth coordination polymerization. Macromolecules. 2007;40:7733–7735.
102. Müller RH, et al. Solid lipid nanoparticles (SLN) for controlled drug delivery—A review of the state of the art. Eur J Pharm Biopharm. 2000;50:161–177.
103. Pragati S, et al. Solid lipid nanoparticles: a promising drug delivery technology. Int J Pharm Sci Nanotechnol. 2009;2:509–516.
104. Freitas C and Müller RH. Correlation between long-term stability of solid lipid nanoparticles (SLN(TM)) and crystallinity of the lipid phase. Eur J Pharm Biopharm. 1999;47:125–132.
105. Olbrich C, et al. Lipid-drug-conjugate (LDC) nanoparticles as novel carrier system for the hydrophilic antitrypanosomal drug diminazenediaceturate. J Drug Targeting. 2000;10:387–396.
106. Lee SH, et al. Nano spray drying: a novel method for preparing protein nanoparticles for protein therapy. Int J Pharm. 2011;403:192–200.
107. York P. Strategies for particle design using supercritical fluid technologies. Pharm Sci Technol Today. 1999;2:430–440.
108. Salager JL, et al. Formulation des micro-émulsions par la méthode HLD, Techniques De L'Ingénieur, Génie Des Procédés. 2001;J2:1–20.
109. Li X, et al. Nanoparticles by spray drying using innovative new technology: the Büchi Nano spray dryer B-90. J Controlled Release. 2010;147:304–3.