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Review Article

MEDICINAL PLANTS: AS A SUSTAINABLE AND INNOVATIVE SOLUTION TO COMBAT PLASTIC POLLUTION - A CRITICAL REVIEW

Suresh Kumar Jaiswara[1*], Shreya Mukherjee[2], Shyamalendu Mukhopadhyay[3]

[*1]Associate Professor, Department of Dravyaguna Vigyan, Institute of Post Graduate Ayurvedic Education & Research, Kolkata.

[2]M.B.B.S. Student at Nil Ratan Sircar Medical College and Hospital, Kolkata.

[3]Director, ISM Drug Control, Govt. of West Bengal, Director, State Medicinal Plant Board, Govt. of West Bengal, and Head Department of Dravyaguna Vigyan, J.B.Roy State Ayurvedic Medical College and Hospital, Kolkata.

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ABSTRACT

With the advancement of human civilization, their population and need also increased exponentially. To cope up with such overgrown requirement many temporary, cheaper and cost-effective solutions have emerged. Plastic is one of such innovation of human which initially revolutionized but later on mankind have to pay for this as plastic pollution in the form of nano-plastic in their ecosystem, food, DNA and even in their sperm. The main reason for plastic pollution is their irresponsible use and almost non-degradable nature for 20 to 500 years. This non-degradable nature of plastic causes them to remain in the ecosystem and disrupt it. These micro-plastics severely harms the aquatic and coastal ecosystem. The micro-plastic levels in different coastal and marine ecosystem ranges from 10^{-3} to 140 particles/m^3 in water and 0.2 to 8766 particles/m^3 in sediments at different aquatic ecosystems worldwide. Micro-plastic accumulation rate in coastal and marine organism varies from 10^{-1} to 15,033 counts. Medicinal plants and their products can be a reasonable and alternative solution for this hazard and this synthetic plastic can be substituted by medicinal plant's bio-plastic which is 100% bio-degradable and eco-friendly. In this review article, authors have critically reviewed the different available research articles and tried to give a comprehensive and summarized solution for the research problem.

INTRODUCTION

Plastic is a large molecular material derived from synthetic and semi-synthetic polymers as well as naturally obtained from the rubber and silk and now it has become a common part of our daily lives. *Bakelite* was the first synthetic plastic invented at the beginning of 20th Century (1907) and supposed to be a revolutionary change in material because of it malleability and molding ability. But, as the time passes it has started showing its negative impact on mankind disrupting the ecological equilibrium, ecosystem and ruining the aesthetical value of nature by litter of single use plastic mainly. And at the end of 20th century micro-plastic has been detected in human sperm. Plastic pollution is the consequence of man-made plastic built up in nature including oceans and seas as they resist breaking down, sometimes, taking 20 to 500 years or more. Recycling of plastic helps in curbing it to some extent but it is not absolute solution because of the improper disposal practices and lack of knowledge. [1]

Marine and coastal environments are the highly productive zones for coral reefs and sea grasses with rich biodiversity of primitive and advanced organisms. The marine ecosystem comprises 71 percentage of Earth's surface and are the witness of various historical, cultural, geographical and scientific events. [2]

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Source of Micro plastics and Nano-plastics in the Environment

Environmental micro-plastic pollution mainly results from the land-based activities like hiking, coastal tourism and fishing whereas fractional traces may occur from the sea. It is estimated that over 800 million tons of aquatic plastic pollution is the contribution of the land-based activities in coastal areas. Aquatic plastic pollution travels worldwide through rivers and oceans and remain present in soil due to erosion. A data from the United Nations Environment Program shows that 275 million tons of plastic waste were produced in the year 2010 of which an estimated amount of 4.8 to 12.7 million tons are again leaching way into the aquatic ecosystem. Biodegradation of plastic is done by bacteria while its non-biodegradation occurs due to chemical and thermal catalyst especially at a faster rate in coastal region due to UV radiation, high temperature and presence of salt from ocean. [7, 8, 9, 10]

MATERIALS AND METHODS

Extensive literary research from various journals, books and online available sources have been carried out to gather the valid scientific information on the topic and all the information have been systematically compiled. Research articles, books and journals such as Encyclopaedia Britannica, PubMed, and Google Scholar were referred as sources of online materials to obtain the information on the topic.

OBSERVATIONS AND DISCUSSION

Effect of plastic pollution

Now-a-days, plastic in nano form has contaminated the food, human sperm and even DNA. Plastic pollutants in the ecosystem is traced in various size variations like mega-plastic, macro-plastic, meso-plastic and micro-plastic, among which, last one is the most harmful for aquatic flora and fauna. Smaller and fiber-shaped micro-plastic shows more toxicity.

It has been observed that plastic pollution has put its obnoxious impact like entanglement to big aquatic creatures like shark, whales, turtles, accidental ingestion lead toxicity, suffocation to smaller aquatic lives, starvation due to blockage of plastic and introduction of new invasive species posing growing threats to biodiversity and trophic relationships. Because of this emerging man-made environmental contamination, many socio-economic adverse impact to tourism, fishery, shipping and human health have been observed. [3, 4]

Plastic pollution has also disrupted nesting of animals and nutrient cycle of soil, potentially impacting the human health through consumption of these contaminated food. Micro-plastics along with plasticizers and chemicals clog the soil particles hindering water infiltration causing soil erosion and drought. Micro-plastics can absorb and adsorb essential plant nutrients disrupting nutrient cycle causing altered and weak plant growth in the ecosystem. Plastic pollution also disrupt pollinators, soil organism, predators leading to gross disturbance in predator-prey relationship and ultimately hampering the food-web. Disruption in ecosystem function will impact on food security, particularly in vulnerable species. [5]

Plastic in human body

Micro-plastic contamination in human body is borne by three routes. The first and most common route is oral, through sea foods, salts, drinking water, honey, beers etc. The second route is through respiration and third one is cosmetics through dermal cream.[11,12,13]

Control measures for plastic pollution

Various methods can be adopted for curbing and controlling this man-made disaster in the form of plastic pollution. UV rays present in sunlight also causes photo-degradation of micro-plastics in photic zone of sea water[34]. Other measures are being discussed here:

A. **Eco-friendly Concept:** The eco-friendly measures includes the following steps.
   a. **Reduced use:** By collaborative efforts of society, government and NGOs, steps can be taken to fully curb the single-use plastics. [14]
   b. **Re-use:** To promote the re-usability of plastic among the common peoples, best quality and broad variety of the plastic can be used. This will curb the waste production of single used plastic. [15]
   c. **Recycle:** Polymer based plastics can be more efficiently used for new applications. [16]

B. **Bio-degradation by micro-organisms:** Bio-degradation of plastic occurs in three steps.[17]
   a. **Bio-deterioration:** Breakdown of environmental plastic by micro-organisms like bacteria, fungi, algae and insects.
   b. **Bio-fragmentation:** Due to natural decomposition processes, larger materials are broken down into smaller pieces by micro-organisms.
   c. **Assimilation:** The bio-degraded and defragmented materials are absorbed by the micro-organism in the form of their nutrients.

C. **Degradation of micro-plastics using medicinal plants:** The enzymes from the medicinal plants are used for the degradation of plastics. Some of the medicinal plants which can be used for the degradation of plastics are as follows.
   a) **Gelatin and Papaya:** The enzymes like gelatinase and papain found in gelatin and papaya latex cause breakdown of polyethylene

terephthalate (PET) which is a common plastic used in bottle and food packaging industry. [18]

b) Ginger: Zingiberine and protease, the two enzymes, are exhibiting degrading effect on polyethylene (PE) and Polysterene (PS) which are widely used component of plastic industry. [19]

c) Turmeric: The curcumin, one of the most important component of the turmeric, has been showing degrading potential to low density polyethylene (LDPE), a certain type of plastic. [20]

D. Myco-remediation with medicinal mushrooms

a) Ganoderma lucidum (Reishi): The enzymes present in them have degrading effect on certain types of polyurethane foam (PU foam) and they also shows symbiotic relation with some bacteria causing plastic degradation.

b) Pleurotus ostreatus (Oyster mushroom): These mushrooms can degrade the most complex molecule known as lignin found in some plastics. [21]

E. Symbiosis of medicinal plants with composting or microbial consortia

A group of two or more micro-organism living together in a symbiotic relationship and acting as composting measures for nano-plastic pollution. This type of microbial association is termed as *consortium.* Some examples of medicinal plants and microbial consortia symbiosis are as follows:

a) Jatropha curcas (Physic nuts): Consortia is formed by Pseudomonas putida and bacillus species. [22,23,24]

b) Hypericum perforatum (St. John's wort): Consortia is formed by Arbuscular mycorrhizal fungal species. [25,26]

c) Azadirachta indica: Consortia is formed by Piriformospor putida and Azotobacter chroococcum species.

d) Andrgraphis paniculata: Consortium is formed by Endophytic bacterial species like bacillus sp. Pseudomonas sp. etc.

e) Zingiber officinale: Consortium is formed by Endophytic fungal species like trichoderma sp. Penicillium sp. etc. [27-33]

F. Medicinal plants as an greener alternative to plastic [35-39]

We know that less use, re-use and recycle are the three basic eco-friendly concept of curbing the plastic pollution and, noteworthy, about 10 Countries uses 43 types of greener packaging labels to reduce the plastic pollution in their country. The measures taken are as follows:

a. Bio-degradable and Compostable material

These materials include medicinal plant resins, mushrooms mycelium etc. which breakdown naturally in the ecosystem and reduces the landfill waste.

b. Re-usable packaging

Re-usable containers, bags and bottles are also the effective eco-friendly measures to minimize the plastic waste.

G. Medicinal plants-based packaging materials

Many medicinal plants contain some specific metabolites and biomolecules which can be used as bio-plastic for greener packaging solution. Some are being discussed here.

a. Corn starch: It contains secondary metabolites like ferulic acid, p-Coumaric acid, flavonoids, anthocyanins, tocopherols, tocotrienols, phytic acid etc. which produces bio-ethanol which is converted into polyethylene terephthalate (PET), a common plastic material. It also produces bagasse. [40]

b. Cellulose: It contains secondary metabolites like harzianum, clostridial toxins, gonodema lucidum etc. which can be molded into bio-degradable and compostable trays, clamshells and other packaging materials. [41]

c. Mushroom mycelium: It contains secondary metabolites like β-glucans, ergosterol, gonoderic acids, cordycepin, hericenones, erinacines, mycolactones, proteases, lipases and cellulases which are bio-degradable materials have potentials to replace bubble wraps and insulating materials. [36]

d. Large leaves and skins of banana and grapes: It contains secondary metabolites like quercetin, gallic acid, chlorogenic acids, matairesinol, lericiresinol, mussaendaine, steroidal saponins, inulin etc. which are compostable and waterproof material and are the better eco-friendly solution for packaging industry. [42-44]

e. Alagae-derived materials: It contains secondary metabolites like astaxanthin, fucoxanthin, phlorotannins, flavonoids, phenolic acids, alginates, omega-3 fatty acids, eicosapentaenoic acids (EPA), which produces various types of bio-plastics used for altering the proportions of polymers, plasticizers (DEHP & DINP) and additives in the mixture. [45]

f. Bamboo: It contains secondary metabolites like orientin, homo-orientin, luteolin, apigenin, ferulic acid, p-Coumaric acid, coumarins, bambusinine, β-glucans, etc. which are used to make durable cardboard in paper industry. [46]

g. **Hemp**: It contains secondary metabolites like cannabidiol (CBD), tetrahydrocannabidiol (THcbd), minor cannabinoid, flavonoids, omega-3 FA, omega-6 FA etc. These fibers are strong and versatile bio-degradable materials ideal for making cardboard, re-usable bags, seed papers at industrial level. [47]

h. **Seed papers**: Embedded seed papers used as packaging materials are an effective way to reduce waste and also add fun element in packaging. Common examples of seeds used in embedded packing are tomato, lettuce, carrot, basil, tri-herb blend (basil, parsley and oregano). Such type of packaging are very helpful for reducing the waste in a very eco-friendly manner. [48,49]

i. **Mushroom packaging**: Mushroom packaging is also an example of embedded packaging. Here packing can be infused with seeds and planted after use promoting both sustainability and urban gardening. [36]

j. **Other eco-friendly measures:** Other measures may be included as use of eco-bricks made up of non-degradable plastics. [50,51]

CONCLUSION

From the above observations and discussion derived on the basis of extensive literary research from various published journals, many factors influencing our ecosystem and bio-diversity directly or indirectly which imply to curb the plastic pollution have been found. Micro-plastic, particularly, is very harmful to aquatic life and they enter human body through many sources, specially, through seafood. Enzymes like gelatinase, papain, zingiberine and protease and curcumin obtained from gelatin, papaya, ginger and turmeric has shown potential plastic degrading action. Further, medicinal mushrooms like Reishi and Oyster mushroom have also possessed plastic degrading properties. Additionally, it has also been found that many medicinal plants or their product or bye-product such as corn starch, sugarcane, cellulose, mushroom mycelium, various leaves etc. can be used as an alternative or substitute to plastic. Eco-friendly measures like limiting or curbing the use of plastic by promoting social awareness about the disastrous consequences of plastic are also a promising solution. Other measures like re-use and recycling of the same plastic bags can also be practiced as an eco-friendly measure. Contribution of medicinal plants such as banana leaves, bamboo and algae-derived products etc. for making trays, clamshells, bubble wraps are also an innovative step in bio-plastic production. Finally, the authors are very much hopeful that this article will surely serve its purpose and help other researchers and interested scholar to quench their queries.

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Authors Contributions

The corresponding author is responsible for the concept, extensive literature review and critical analysis of the data. The second and third authors have provided data from their extensive literature research and journal review. All the necessary reviews of the final version of manuscript have been carried out by all the three authors before the submission of this article.

Conflict of Interest

All the three authors declare that there is no any conflict of interest for this review article.

REFERENCES

1. Moor Charls, Fact-checked by: Editors of Encyclopaedia Britannica, Last Updated: Jan 8, 2024 Article History plastic pollution See all media, Category: Animals & Nature, Related Topics: Plastic micro-plastics pollution biodegradation.
2. Thushari G.G.N., Senevirathna J.D.M., Review article: Plastic pollution in the marine environment, Department of Animal Science, Faculty of Animal Science and Export Agriculture, Uva Wellassa University, Badulla, Sri Lanka.
3. Kwan So Mandy Wing, Vorsatz Lyle Dennis, Cannicci Stefano, Christelle. Fate of plastic in the environment: From macro to nano by macrofauna.
4. Rai Prabhat Kumar, Lee Jechan, Richard Brown J.C., Kim Ki-Hyu, Micro and Nano Plastic: Review Micro- and nano-plastic pollution: Behavior, microbial ecology, and remediation technologies.
5. Reddy Simon, Plastic Pollution Affects Sea Life Throughout the Ocean Photos document extent of the impact, which extends to the seafood people eat, ARTICLE September 24, 2018, Projects: Preventing Ocean Plastics.
6. Sigler Michelle, The Effects of Plastic Pollution on Aquatic Wildlife: Current Situations and Future Solutions Published: 18 October 2014 Volume 225, article number 2184, (2014).
7. Swee-Li Yee Maxine, Wei Hii Ling, Looi Chin King, Lim Wei-Meng, Wong Shew-Fung, Kok Yih-Yih, et al. Impact of Microplastics and Nanoplastics on Human Health.

8. Browne, M.A.; Crump, P.; Niven, S.J.; Teuten, E.; Tonkin, A.; Galloway, T.; Thompson, R. Accumulation of Microplastic on Shorelines Worldwide: Sources and Sinks. Environ. Sci. Technol. 2011, 45, 9175–9179. [Google Scholar] [Cross Ref]
9. Browne, M.A.; Underwood, A.J.; Chapman, M.G.; Williams, R.; Thompson, R.C.; Van Franeker, J.A. Linking effects of anthropogenic debris to ecological impacts. Proc. R. Soc. B Boil. Sci. 2015, 282, 20142929. [Google Scholar] [Cross Ref] [PubMed] [Green Version]
10. Thushari, G.; Senevirathna, J. Plastic pollution in the marine environment. Heliyon 2020, 6, e04709. [Google Scholar] [Cross Ref]
11. Sharma Shreya, Sharma Bhasha, Sadhu Susmita Dey, Microplastic profusion in food and drinking water: Are microplastics becoming a macroproblem?
12. Microplastics in air: Are we breathing it in? Author Johnny Gasperi 1 a, Stephanie L. Wright 2 a, Rachid Dris 1, France Collard 1, Corinne Mandin 3, Mohamed Guerrouache 4, Valérie Langlois 4, Frank J. Kelly 2, Bruno Tassin 1.
13. H.A. Leslie, Review of Microplastics in Cosmetics Scientific background on a potential source of plastic particulate marine litter to support decision-making, IVM Institute for Environmental Studies.
14. Walther Bruno Andreas, Yen Ning, Hu Chieh-Shen, Strategies, actions, and policies by Taiwan's ENGOs, media, and government to reduce plastic use and marine plastic pollution.
15. Rajmohan Kunju Vaikarar Soundararajan, Ramya Chandrasekaran, Viswanathan Manakkal Raja, Varjani Sunita, Plastic pollutants: Effective waste management for pollution control and abatement.
16. Millican Jonathan M., Agarwal Seema Plastic Pollution: A Material Problem? [internet]
17. Khan Amna Komal, Majeed Tanveer, Biodegradation of Synthetic and Natural Plastics by Microorganisms: A Mini Review, Department of Biotechnology, Kinnaird College for Women, Lahore, Pakistan.
18. Jaweria Ashfaq, Ahmed Channa Iftikhar, Ahmed Shaikh Asif, Dad Chandio Ali, Ahmed Shah Aqeel, Bushra Bughio, Ashfaque Birmahani *et al*., Gelatin- and Papaya-Based Biodegradable and Edible Packaging Films to Counter Plastic Waste Generation.
19. Mehata Mohan Singh, Green route synthesis of silver nanoparticles using plants/ginger extracts with enhanced surface plasmon resonance and degradation of textile dye.
20. Gowthaman N.S.K., Lim H.N., Sreeraj T.R., Amalraj Augustine, Gopi Sreeraj, Chapter 15 -Advantages of biopolymers over synthetic polymers: social, economic, and environmental aspects.
21. Ann Denise, Utilizing natural components to combat anthropogenic effects Hassinger. Dighton, John, Rutgers University; Camden Graduate School
22. Mazzoni, Janajreh L. and I., Plasma gasification of municipal solid waste with variable content of plastic solid waste for enhanced energy recovery. Int. J. Hydrog. Energy. 42(30): 19446–19457. (2017)
23. Saminathan Ponniah, Sripriya Anandan, Nalini Kaliappan, Sivakumar Thangavelu, Thangapandian Veerapandiyan: Biodegradation of Plastics by Pseudomonas putida isolated from Garden Soil Samples, Sasham biologicals, Department of Microbiology, Ayya Nadar Janaki Ammal College, Sivakasi, India.
24. Patel Dhara, Saraf Meenu, Influence of soil ameliorants and microflora on induction of antioxidant enzymes and growth promotion of Jatropha curcas L. under saline condition.
25. Khan Zeeshan, Shah Tariq, Asad Muhammad, Amjad Khadija, Alsahli Abdulaziz Abdullah, Ahmad Parvaiz.: Alleviation of microplastic toxicity in soybean by arbuscular mycorrhizal fungi: Regulating glyoxalase system and root nodule organic acid.
26. Zubek Szymon, Mielcarek Sebastian & Turnau Katarzyna.,: Hypericin and pseudohypericin concentrations of a valuable medicinal plant Hypericum perforatum L. are enhanced by arbuscular mycorrhizal fungi Original Paper Open Access Published: 28 May 2011 Volume 22, pages 149–156, (2012).
27. De Tender Caroline A., Devriese Lisa I., Haegema Annelies, Maes Sara, Ruttink Tom, and Dawyndt Peter.: Bacterial Community Profiling of Plastic Litter in the Belgian Part of the North Sea.
28. Verma, Poonam & Shakya, Mridul & Swamy, N Kumar & Sandhu, Sardul. (2022). Microbial consortium: A innovative steps in environmental protection. 10.1016/B978-0-323-90590-9.00023-7.
29. Bandyopadhyay P, Yadav BG, Kumar SG, Kumar R, Kogel KH, Kumar S. Piriformospora indica and Azotobacter chroococcum Consortium Facilitates Higher Acquisition of N, P with Improved Carbon Allocation and Enhanced Plant Growth in Oryza sativa. J Fungi (Basel). 2022 Apr 27; 8(5): 453. doi: 10.3390/jof8050453. PMID: 35628709; PMCID: PMC9146537.
30. Yadav, Gaurav & Srivastva, Rishita & Gupta, Preeti. (2021). Endophytes and Their Applications as Biofertilizers. 10.1007/978-981-16-3840-4_7.
31. Bagde, U.s & Prasad, Ram & Varma, Ajit. (2011). Interaction of Mycobiont: Piriformospora Indica with Medicinal plants and plants of Economic

importance. African Journal of Biotechnology. 9. 9214-9226.

32. Kumari, Poonam & Shanker, Karuna & Singh, Akanksha. (2023). Insight into Andrographis paniculata associated bacterial endomicrobiome and assessment of culturable bacterial endophytes for enhancement of industrially important andrographolide content. Industrial Crops and Products. 200. 116840. 10.1016/j.indcrop.2023.116840.
33. Kumar,S. P. M. and Chowdappa,P. and Krishna,V., 20153196064, India, 68, (1), New Delhi, Indian Phytopathology, (25–31), Indian Phytopathological Society, Development of seed coating formulation using consortium of Bacillus subtilis OTPB1 and Trichoderma harzianum OTPB3 for plant growth promotion and induction of systemic resistance in field and horticultural crops.
34. M'rabet C, Kéfi-Daly Yahia O, Couet D, Gueroun SKM, Pringault O. Consequences of a contaminant mixture of bisphenol A (BPA) and di-(2-ethylhexyl) phthalate (DEHP), two plastic-derived chemicals, on the diversity of coastal phytoplankton. Mar Pollut Bull. 2019 Jan; 138: 385-396. doi: 10.1016/j.marpolbul.2018.11.035. Epub 2018 Nov 29. PMID: 30660288.
35. Sarwar Suleman, Streimikiene Dalia, Waheed Rida, Rauf Abdul. Public Health, Governance, Green Environment and Economy<frontiers in Public Health
36. R, Abhijith & Ashok, Anagha & C R, Rejeesh. (2018). Sustainable packaging applications from mycelium to substitute polystyrene: A Review. Materials today: proceedings. 5. 2139-2145. 10.1016/j.matpr.2017.09.211.
37. Stabingytė, Lina. Design of Plant-Based Biodegradable Plastic Composites for Sustainable Packaging. Master's Final Degree Project, supervisor lect. Laura Gegeckienė; Faculty of Mechanical Engineering and Design, Kaunas University of Technology.
38. Garrison TF, Murawski A, Quirino RL. Bio-Based Polymers with Potential for Biodegradability. Polymers (Basel). 2016 Jul 14; 8(7): 262. doi: 10.3390/polym8070262. PMID: 30974537; PMCID: PMC6432354.
39. Coelho, Patricia & Corona, Blanca & ten Klooster, Roland & Worrell, Ernst. (2020). Sustainability of reusable packaging - Current situation and trends. Resources, Conservation & Recycling: X. 6. 100037. 10.1016/j.rcrx.2020.100037.
40. Abotbina W, Sapuan SM, Sultan MTH, Alkbir MFM, Ilyas RA. Development and Characterization of Cornstarch-Based Bioplastics Packaging Film Using a Combination of Different Plasticizers. Polymers (Basel). 2021 Oct 11; 13(20): 3487. doi: 10.3390/polym13203487. PMID: 34685246; PMCID: PMC8539400.
41. Patil H, Sudagar IP, Pandiselvam R, Sudha P, Boomiraj K. Development and characterization of rigid packaging material using cellulose/sugarcane bagasse and natural resins. Int J Biol Macromol. 2023 Aug 15; 246: 125641. doi: 10.1016/j.ijbiomac.2023.125641. Epub 2023 Jun 30. PMID: 37394220.
42. Arumugam, Soundhar & Pugazhenthi, G. & Senthilvelan, Selvaraj. (2023). Investigations on mechanical properties of processed banana leaves for sustainable food packaging applications. Materials Today Proceedings. 10.1016/j.matpr.2023.02.256
43. Díaz-Galindo EP, Nesic A, Cabrera-Barjas G, Mardones C, von Baer D, Bautista-Baños S, Dublan Garcia O. Physical-Chemical Evaluation of Active Food Packaging Material Based on Thermoplastic Starch Loaded with Grape cane Extract. Molecules. 2020 Mar 13; 25(6): 1306. doi: 10.3390/molecules25061306. PMID: 32182987; PMCID: PMC7144104.
44. Kumar S, Boro JC, Ray D, Mukherjee A, Dutta J. Bionanocomposite films of agar incorporated with ZnO nanoparticles as an active packaging material for shelf-life extension of green grape. Heliyon. 2019 Jun 5; 5(6): e01867. doi: 10.1016/j.heliyon.2019.e01867. PMID: 31198876; PMCID: PMC6555880.
45. Dang BT, Bui XT, Tran DPH, Hao Ngo H, Nghiem LD, Hoang TK, Nguyen PT, Nguyen HH, Vo TK, Lin C, Yi Andrew Lin K, Varjani S. Current application of algae derivatives for bioplastic production: A review. Bioresour Technol. 2022 Mar; 347: 126698. doi: 10.1016/j.biortech.2022.126698. Epub 2022 Jan 11. PMID: 35026424.
46. Khadoo, Pratima & Purrahoo, Ameenah. (2021). Production of Packaging and Value-Added Material from Bamboo Biomass. Journal of Packaging Technology and Research. 6. 10.1007/s41783-021-00127-y.
47. Lo, Chi & Mutukumira, A.N. & Wade, Kelly & Parker, Kate & Sloane, Michelle. (2024). Sustainable paper-based packaging from hemp hurd fiber: A potential material for thermoformed molded fiber packaging. Bio Resources. 19. 1728-1743. 10.15376/biores.19.1.1728-1743.
48. Chisenga, Shadrack & Tolesa, Getachew & Seyoum Workneh, Tilahun. (2020). Review Article Biodegradable Food Packaging Materials and Prospects of the Fourth Industrial Revolution for Tomato Fruit and Product Handling. International Journal of Food Science. 2020. 17. 10.1155/2020/8879101.
49. Janowicz M, Galus S, Ciurzyńska A, Nowacka M. The Potential of Edible Films, Sheets, and Coatings

Based on Fruits and Vegetables in the Context of Sustainable Food Packaging Development. Polymers (Basel). 2023 Oct 26; 15(21): 4231. doi: 10.3390/polym15214231. PMID: 37959909; PMCID: PMC10648591.

50. Edike, Uche & Ameh, John & Dada, Martin. (2020). Production and optimization of eco-bricks. Journal of Cleaner Production. 266. 121640. 10.1016/j.jclepro.2020.121640.
51. Kumar, Rishabh & Kumar, Mohit & Kumar, Inder & Srivastava, Deepa. (2021). A review on utilization of plastic waste materials in bricks manufacturing process. Materials Today: Proceedings. 46. 10.1016/j.matpr.2021.04.337.

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***Address for correspondence**
Dr. Suresh Kumar Jaiswara
Associate Professor,
Department of Dravyaguna Vigyan,
Institute of Post Graduate Ayurvedic Education & Research, Kolkata.
Email: dr.sureshkjaiswara@gmail.com