longa L.) - A review. *J Food Sci Technol.* 2008, 45(2), 109–116.

12. Domina, P. M. D. Health benefits of turmeric. doi:10.13140/RG.2.2.31582.25929

13. Srinivas, P.; Nirmala, G.; Bhavani, S.; Sindhu, K. Post-harvest practices, processingand value addition of turmeric in Advances in post-harvest management, processing and value addition of horticultural crops part - 2: Vegetable, spices & plantation crops. Today & tomorrow's printers and publishers, 2019, 399-413.

14. Reeta, V. and Kalia, S. Turmeric: A review of its' effects on human health. *Journal of medicinal plants studies.* 2022, 10(4), 61-63. DOI: 10.3390/foods6100092

15. Salem, M. A.; El Shiekh, R. A.; Fernie, A. R.; Alseekh, S.; Zayed, A. Metabolomics based profiling for quality assessment and revealing the impact of drying of Turmeric (*Curcuma longa* L.). *Scientific reports.* 2022, 12, 10288. DOI:10.1038/s41598-022-13882-y

16. Idowu-Adebayo, F.; Fogliano, V.; Linnemann, A. Turmeric-fortified Cow and soya milk: Golden milk as a street food to support consumer health. *Foods.* 2022, 11(4), 558. DOI: 10.3390/foods11040558

17. Orellana-Paucar, A. M.; Machado-Orellana, M. G. Pharmacological profile, bioactivities, and safety of turmeric oil. *Molecules.* 2022, 27, 5055. doi 10.3390/molecules27165055

Professor K Sarath D Perera *obtained his BSc from University of Sri Jayewardenepura and completed his PhD in Queen's University Belfast, UK. He is currently serving as a Senior Professor at the Department of Chemistry, Open University of Sri Lanka.*

Ms. A. D. Theeshya Dulmini *graduated from the Open University of Sri Lanka and obtained her MSc. in Analytical Chemistry from the University of Colombo.*

Guest Articles

Advanced Applications of Poly (lactic acid)

Dinesh C. Aluthge

Department of Chemistry, University of Colombo

Poly(lactic acid) (PLA) is a biodegradable, compostable and biocompatible polyester. PLA was first synthesized by Wallace Hume Caruthers at DuPont in 1932 via the polycondensation of lactic acid. However, the modern industrial process for PLA synthesis, polymerizes lactide, the cyclic diester of lactic acid (Figure 01). Lewis acid catalysts are used for the ring-opening polymerization (ROP) of lactide. The lactic acid needed to produce lactide is produced through the fermentation of an agricultural feedstock such as corn starch or sugar beet pulp. Poly(lactic acid) along with thermoplastic starch dominate the global biopolymer market.

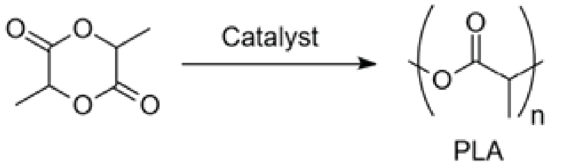

Figure 1: Ring-opening polymerization of lactide

Lactide occurs in three isomeric forms, L-lactide, D-lactide and meso-lactide (Figure 02). Due to the presence of stereocenters along the polymer backbone, the stereoregularity or the tacticity of the polymer has a significant impact on thermomechanical properties of PLA. A large body of academic literature has focussed on developing stereoselective catalysts for lactide polymerization. These are often catalysts with ligands of varying complexity attached to a Lewis acidic metal centre. In general, an equimolar mixture of L- and D- lactide (racemic lactide) is used in academic research on stereoselective polymerization. However, in the industrial monomer feedstocks, L-lactide is by far the most abundant stereoisomer present (though some D-lactide and meso-lactide can be present due to racemization) because the natural enantiomer of lactic acid, L-lactic acid is formed in starch fermentation. The industrial polymerization catalyst is usually a simple tin alkoxide salt.

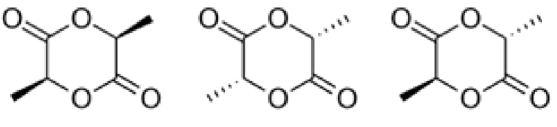

Figure 2: Stereoisomers of lactide

Most commercial uses of PLA are for low-end applications such as food packaging, plastic cutlery, and sheets. In these cases, the selling point for PLA use is to replace a non-degradable commodity plastic such as polyethylene or polystyrene with a biodegradable and compostable alternative. Another important use of PLA is for biomedical applications. Dissolving medical sutures and a variety of implants and prosthetics are made from PLA. The biocompatibility of PLA is an important factor for such applications. PLA when it degrades produce lactic acid which can readily metabolize via the citric acid cycle. Significant efforts have been made into improving thermal and mechanical properties of PLA to enable its use in consumer electronics and automotive industry. The enhanced properties such as improved thermal resistance has largely been achieved using different processing methods and creating blends of PLA to promote the formation of crystallites. While this will enable PLA to replace common commodity plastics in more applications, arguably the most interesting areas of PLA use is in more advanced and speciality applications ranging drug delivery to 3D printing.

PLA is widely used in the biomedical industry due to its biodegradable and biocompatible nature. Recent research has focussed on expanding its utility from implants and prosthetics to more specialized uses such as controlled release and delivery of pharmaceutics. PLA based agents have been used to form various types of aggregates in solution that can encapsulate organic small molecules as well as proteins. The release of the drugs while aided by a variety of mechanisms generally rely on the hydrolytic ester cleavage of the polyester backbone. Size of these particles can range from nanoparticles to microparticles. PLA is sometimes copolymerized with other polymers such as poly(glycolic acid) for these applications. Another important application of PLA is its use in tissue engineering. Various tissues are harvested and cultured on biostable surfaces and as the cells establish themselves the supporting scaffold would degrade and disappear leaving behind new tissue at the implant site. PLA due to its biodegradable and biocompatible nature has long been explored as an ideal candidate for such supports.

To enhance the mechanical properties and broaden the scope of applications of PLA, many different polymer composites have been produced. In polymer composite production a polymer matrix is blended and reinforced with a filler, that can improve specific properties of the final material. Often with PLA, natural fibres are used to form composites. Many PLA composites, reinforced with fibres such as jute, cotton, silk and flax exhibit significant increase (up to 50%) in strength (measured through elongation and compression) compared to the unaltered polymer. The composite also shows enhancement of other important properties like fire retardancy. These composites have gained significant traction in the automotive industry. Another area of potential use is in the construction industry as replacement for wood paneling; this could enhance the fire resistance of structures and resistance against weevils and termites.

PLA is currently widely used as a Desktop 3D printing material. Most extrusion-based 3D printers use PLA due its relatively low glass transition temperature (50 °C-60 °C). This allows for the use of a 3D printing devices without a heat bed. Biodegradability of PLA coupled with its good shelf life under most environmental conditions and relatively low cost have all contributed to the desirability of PLA 3D printed items. However, certain drawbacks such as low heat resistance and brittleness exist. Various PLA based polymer blends and composites have been developed to mitigate these issues when the application requires it.

In summary, PLA which during the its early years as a commercial polymer was widely looked at simply as biodegradable alternative to commodity plastics has shown significantly more potential in speciality and high-end applications. Widely used in the biomedical sphere as implants and prosthetics PLA has found important applications in areas of drug delivery and tissue regeneration. Significant challenges with undesirable thermomechanical properties of unaltered PLA have been overcome with the production of natural fibre reinforced PLA composites that have found a variety of applications such as automotive parts and 3D printing filaments.

References

1. Dechy-Cabaret, O; Martin-Vaca, B.; Bourissou, D. *Chem. Rev.* **2004**, *104*, 6147–6176.
2. DeStefano, V; Khan, S; Tabada, A. *Eng. Regen.* **2020**, *1*, 76-87.
3. Dana, H.R.; Ebrahimi, F. *Polym. Eng. Sci.* **2022**, *63*, 22-43.
4. Ilyas, R.A.; Sapuan, S.M.; Harussani, M.M.; Hakimi, M.Y.A.Y.; M.Z.M. Haziq et al. *Polymers* **2021**, *13*, 1326-1360.
5. Drumright, R.E.; Gruber, P.R.; Henton, D.E. *Adv. Mater.* **2000**, *12*, 1841–1846.
6. Oksman, K.; Skrifvars, M.; Selin, J.-F. *Compos. Sci. Technol.* **2003**, *63*, 1317–1324.
7. Chen, G. Q.; Patel, M. K.; *Chem. Rev.* **2012**, *112*, 2082–2099.
8. Singhvi, M.S.; Zinjarde, S.S.; Gokhale, D.V. *Appl. Microbiol. Int.* **2019**, *127*, 1612-1626.
9. Muthe, L.P.; Pickering, K.; Gauss, C. *Composites Part A.* **2022**, *8*, 100271- 100296.
10. Taib, NA.A.B. ; Rahman, M.R.; Huda, D. et al. *Polym. Bull.* **2023**, *80*, 1179–1213.

Dr. Dinesh C. Aluthge *graduated from the University of Colombo in 2009, with a Bachelor's degree in Chemistry with First Class Honors. Dr. Aluthge obtained his PhD from the University of British Columbia in 2015, where he worked under the supervision of Prof. Parisa Mehrkhodavandi on developing chiral catalysts for the ring-opening polymerization of cyclic esters. Thereafter, he joined the research group of Prof. John E. Bercaw at the California Institute of Technology as a postdoctoral scholar. Dr. Aluthge's postdoctoral work focused on developing tandem catalytic systems for olefin trimerizations and polymerization reactions. In 2017, he joined Green Centre Canada as a Research Scientist and subsequently held the role of Technical Lead of the Semiconductor Materials Group at Green Centre. In 2022, Dr. Dinesh Aluthge joined the Department of Chemistry, University of Colombo as a Senior Lecturer.*

CHEMISTRY IN SRI LANKA

Chemistry in Sri Lanka is a tri-annual publication of the Institute of Chemistry Ceylon and is published in January, May and September of each year. It is circulated among the members of the Institute of Chemistry and students of the Graduateship/DLTC course and libraries. The publication has a wide circulation and more than 500 copies are published. Award winning lectures, abstracts of communications to be presented at the annual sessions, review papers, activities of the institute, membership news are some of the items included in the magazine.

The editor invites from the membership the following items for publication in the next issue of the Chemistry in Sri Lanka which is due to be released in May 2023.

- *Personal news of the members*
- *Brief articles of topical interests*
- *Forthcoming conferences, seminars and workshops*
- *Latest text books and monographs of interest to chemists*

All publications will be subjected to approval of the 'Editorial and Publicity Committee' and the Council of the Institute of Chemistry Ceylon.

Further, prospective career opportunities for chemists, could be advertised in Chemistry in Sri Lanka at a nominal payment. The editor in chagrge welcomes suggestions from the members for improvement of the publication.