E-PROCEEDINGS

INTERNATIONAL TINKER INNOVATION & ENTREPRENEURSHIP CHALLENGE (i-TIEC 2025)

"Fostering a Culture of Innovation and Entrepreneurial Excellence"

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PTDI, UiTM Cawangan Johor
Kampus Pasir Gudang

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A-ST110: VANMA: A GREEN SOLUTION FOR STRONGER STEEL IN ACIDIC ENVIRONMENTS

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ABSTRACT

Vanillin Meldrum's Acid (VanMA) is an innovative, eco-friendly corrosion inhibitor designed to protect mild steel surfaces in harsh acidic environments, such as 1 M HCl solutions. Developed from vanillin, a natural compound, and Meldrum's acid, a versatile organic molecule, VanMA combines the strengths of both to create an affordable, sustainable, and effective solution for industrial corrosion problems. Its unique molecular structure allows it to form a protective layer on metal surfaces, reducing material degradation and extending the lifespan of infrastructure and equipment. Compared to conventional inhibitors, VanMA requires lower concentrations (0.1 mM) to achieve significant protection, making it a cost-efficient choice for industries such as oil and gas, petrochemicals, and construction. This innovation not only minimizes maintenance and replacement costs but also reduces environmental impact, aligning with global sustainability goals. VanMA's high solubility, thermal stability, and low toxicity make it suitable for large-scale production and integration into existing corrosion management systems. With its commercial potential and environmentally friendly profile, VanMA stands as a promising solution to address industrial corrosion challenges while promoting economic efficiency and environmental responsibility.

Keywords: Meldrum's acid, HCl, corrosion, Vanillin, inhibitor

1. Product Description

Vanillin Meldrum's Acid (VanMA) is an innovative, eco-friendly corrosion inhibitor designed specifically to protect mild steel surfaces in aggressive acidic environments such as 1 M HCl solutions. It is synthesized by combining vanillin, a naturally derived aromatic compound, with Meldrum's acid, a versatile organic molecule. This hybrid compound offers remarkable corrosion inhibition efficiency (62.19%) at a low optimal concentration (0.1 mM), ensuring cost-effectiveness without compromising performance. VanMA forms a protective molecular barrier on steel surfaces, reducing metal degradation and increasing durability. Its high solubility, thermal stability, and low toxicity make it suitable for various industrial applications, including oil and gas, petrochemical processing, and construction sectors. Additionally, VanMA is sustainable and environmentally friendly, minimizing the ecological footprint often associated with traditional chemical inhibitors. The product's affordability, scalability, and environmental safety make it an ideal choice for industries seeking to adopt green corrosion management solutions.

2. Figures.

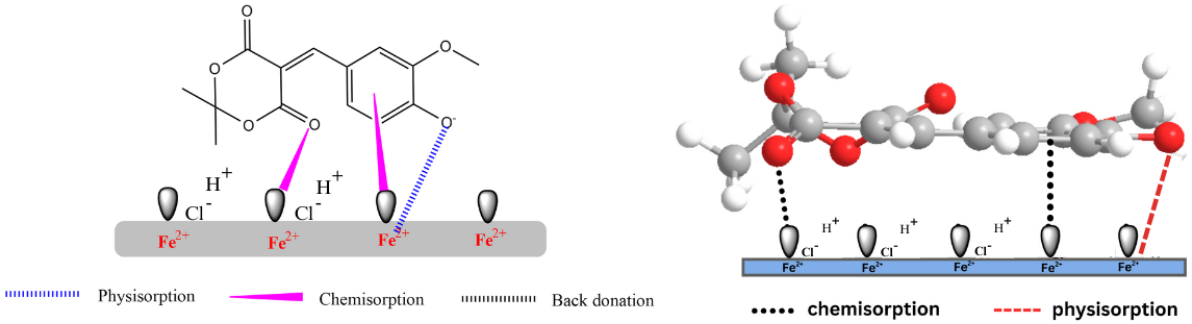

Figure 1. Proposed corrosion inhibition mechanism of VanMA in (a) 2D and (b) 3D.

Table 1. Weight loss data for corrosion inhibition studies at 303K

Concentration (mM)	*Corrosion rate, CR (g cm^{-2} h^{-1})*	*Inhibition efficiency*
Blank	14.60 x 10^{-4}	-
0.02	10.50 x 10^{-4}	27.96
0.04	9.979 x 10^{-4}	32.52
0.06	8.145 x 10^{-4}	44.22
0.08	7.416 x 10^{-4}	54.92
0.10	6.562 x 10^{-4}	62.19

3. Novelty and uniqueness

Vanillin Meldrum's Acid (VanMA) stands out as a novel hybrid corrosion inhibitor by combining the unique properties of vanillin and Meldrum's acid into a single compound. Its innovative molecular design allows it to form a robust protective barrier on mild steel surfaces, minimizing corrosion in highly acidic environments (1 M HCl). Unlike traditional inhibitors, VanMA demonstrates high efficiency (62.19%) at exceptionally low concentrations (0.1 mM), making it an economically viable solution for industrial applications. Its Freundlich adsorption isotherm behavior indicates multilayer adsorption, a rare characteristic among conventional inhibitors. Additionally, VanMA boasts high solubility, thermal stability, and an environmentally friendly profile, addressing both performance and sustainability concerns. Its dual adsorption mechanism (physisorption and chemisorption) ensures a strong and stable interaction with metal surfaces, effectively preventing corrosive damage. These combined features make VanMA a unique, scalable, and

sustainable choice for industries seeking cost-effective and green corrosion control solutions.

4. Benefit to mankind

VanMA offers significant benefits to mankind by providing a sustainable, cost-effective, and environmentally friendly solution to address corrosion-related challenges. By minimizing steel corrosion, VanMA reduces infrastructure failures, repair costs, and resource wastage across critical industries such as oil and gas, construction, and petrochemicals. Its eco-friendly composition ensures reduced environmental pollution and safer handling compared to conventional inhibitors. The low concentration requirement (0.1 mM) translates to reduced chemical waste, making industrial processes more efficient and economical. Moreover, VanMA contributes to sustainability goals, aligning with global efforts to adopt green technologies. Its successful implementation can enhance safety, durability, and operational efficiency, ultimately supporting economic growth and environmental conservation for future generations.

5. Innovation and Entrepreneurial Impact

VanMA fosters a culture of innovation and entrepreneurship by offering an eco-friendly and scalable solution to corrosion-related industrial challenges. Its unique composition and **cost-**effective performance create opportunities for commercial production and market distribution in industries such as oil and gas, construction, and petrochemicals. The project promotes technology transfer, skill development, and local industry growth, empowering institutions and entrepreneurs to explore sustainable corrosion management solutions. By addressing a **g**lobal industrial problem with a green and efficient product, VanMA opens avenues for new startups and collaborations focused on environmentally responsible chemical production. Educational institutions can leverage VanMA research for training programs, workshops, and knowledge-sharing initiatives, cultivating a skilled workforce and inspiring future innovations in sustainable chemistry.

6. Potential commercialization

VanMA exhibits strong commercialization potential due to its cost-effectiveness, scalability, and environmental safety. Its high inhibition efficiency (62.19%) at low concentrations (0.1 mM) minimizes raw material costs, while its thermal stability and solubility make it suitable for diverse industrial applications. VanMA aligns with global sustainability goals and meets regulatory requirements for eco-friendly chemical products. Its adaptability to existing industrial systems ensures seamless integration, reducing transition costs for industries adopting this technology. Strategic partnerships with chemical manufacturers and industrial stakeholders can facilitate large-scale production and distribution, capturing a significant share of the corrosion inhibitor market. As industries increasingly prioritize sustainability and cost efficiency, VanMA emerges as an ideal solution for long-term corrosion management across critical sectors worldwide.

7. Acknowledgment

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8. Authors' Biography

Muhammad Azhan Arif Bin Mansor recently completed a Bachelor of Science (AS222) degree in Chemistry and Management at Universiti Teknologi MARA Kuala Pilah. With a strong foundation in both scientific principles and management strategies, Azhan is equipped to bridge the gap between technical expertise and organizational efficiency. His academic journey emphasized analytical chemistry, environmental sustainability, and effective resource management.

Profesor Madya ChM Dr. Nur Nadia Dzulkifli is an Associate Professor at UiTM Kampus Kuala Pilah, under the Faculty of Applied Sciences. She began her service at UiTM on 15th September 2015 and specializes in Inorganic Chemistry within the Applied Chemistry discipline. With a PhD, Master's, and bachelor's degree in chemistry from Universiti Kebangsaan Malaysia, she is also a Registered Chemist and a professional member of the Institut Kimia Malaysia. Her expertise spans Advanced Experimental and Applied Science, focusing on Industrial Technology (IT). Passionate about innovation and scientific discovery, she contributes significantly to advancing applied chemical sciences.