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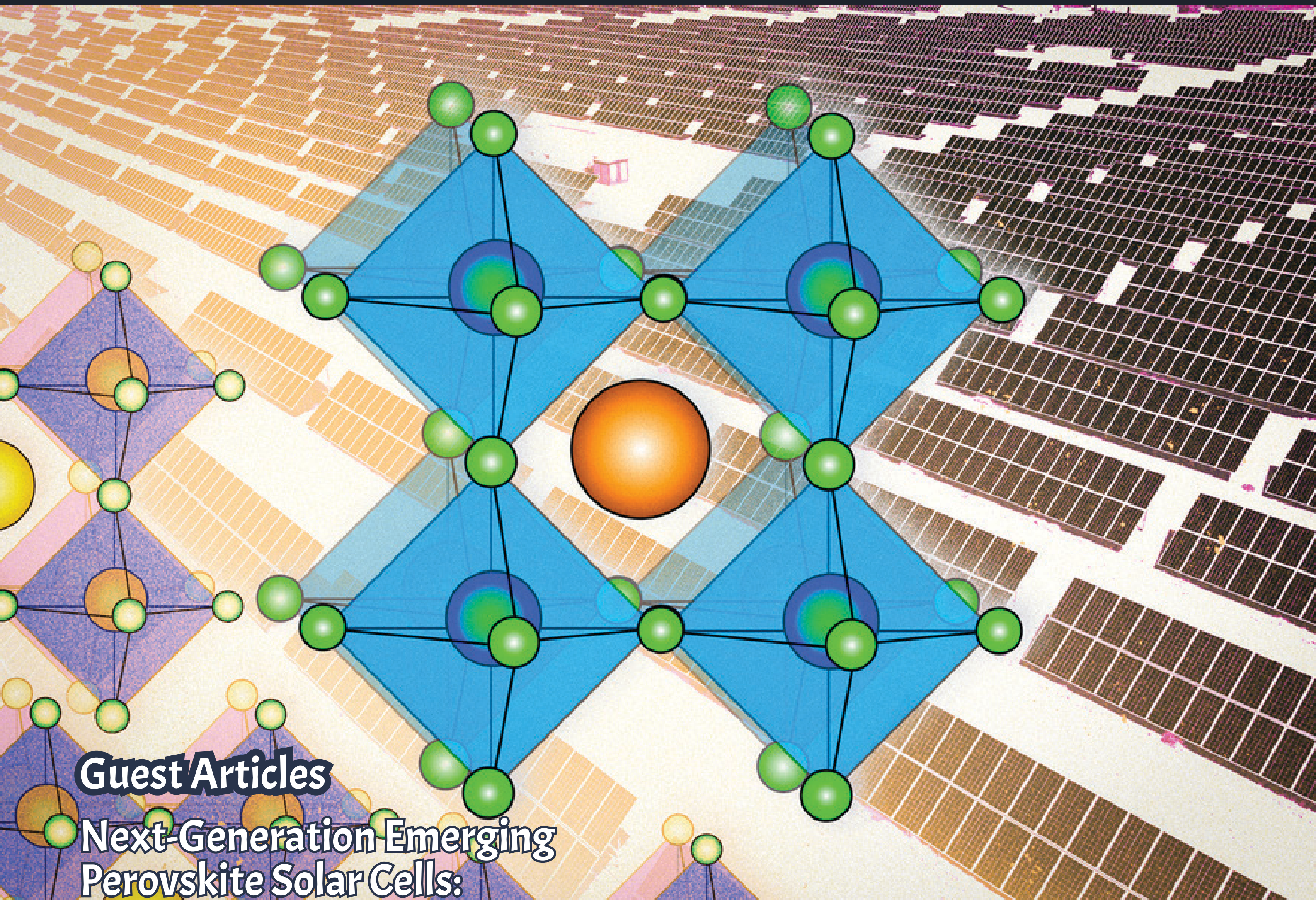

Guest Articles

Next-Generation Emerging Perovskite Solar Cells:
Shaping the Future for Clean and Sustainable Energy

Salt Stress:
An Invisible Threat to Global Food Production

Microplastics:
A Growing Threat to Agricultural Ecosystem

Chemical Advances in Mosquito Repellents

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Founded in 1971, Incorporated by Act of Parliament No. 15 of 1972

Successor to the Chemical Society of Ceylon, founded on 25th January 1941

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Pages

Theme for the year -

Chemistry for Quality Life

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Guest Editorial

Moringa Oleifera: as a source of food, Nutraceuticals, anti-microbial, and an immunomodulating agent

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Introduction

Moringa oleifera, which belongs to the family Moringaceae, is a plant grown in almost all part of Sri Lanka although it is well grown in semi-arid areas. Everybody enjoys its pods, "Murunga" (Drumsticks) as a curry though little attention is paid to its leaves (Figure 1). Several Sri Lankan companies export mainly leaves / leaf - powder to different countries. However, Sri Lanka has never realized its full potential as an export agricultural crop which can bring foreign currency to the country. It grows widely in semi-arid, tropical and subtropical regions in the world and prefers to grow in neutral to slightly acidic (pH 6.3 to 7.0), sandy or loamy soil.

Moringa oleifera contains many important minerals and phytochemicals, such as zeatin, quercetin, beta-sitosterol, caffeoylquinic acid, kaempferol and catechins to name a few (Figure 2).

Figure 1: *Moringa oleifera* leaves
Source: https://www.ebay.com/itm/394353687070

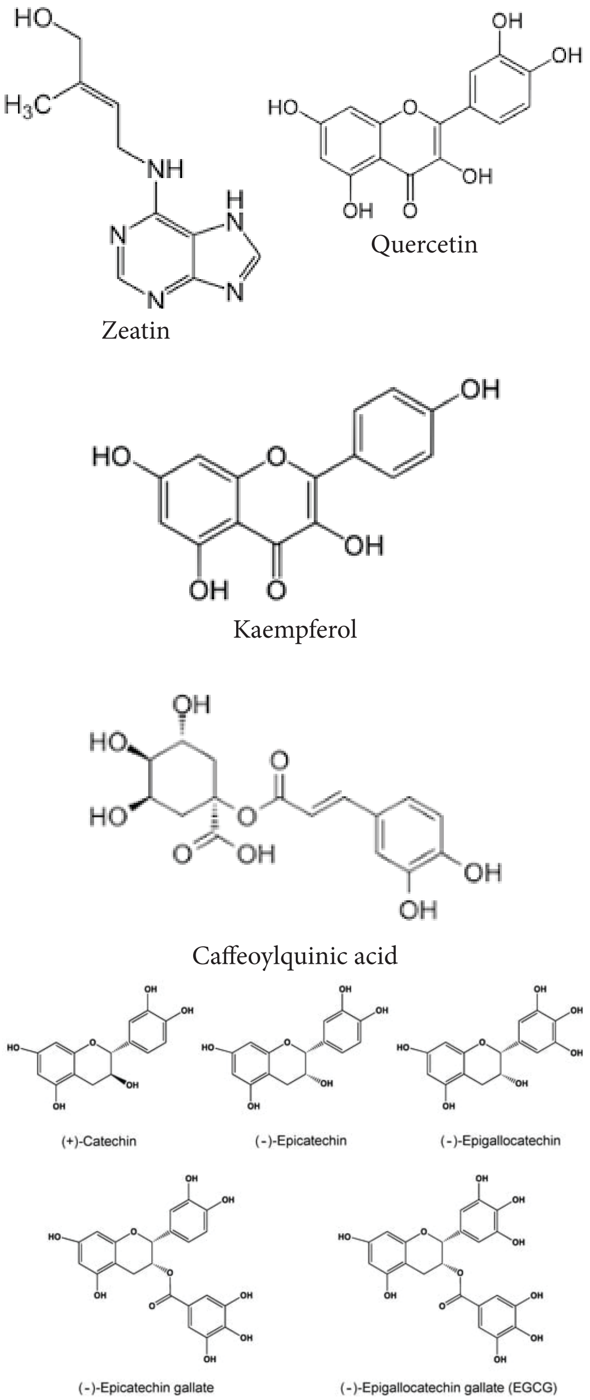

Figure 2: Health beneficial compound of *Moringa Oleifera*

The *in vitro* and *in vivo* studies have confirmed its various biological activities and important medical aspects such as antioxidant, anti-inflammatory, anti-diabetic, anti-cancer, cardioprotective, hypocholesterolemia, hepatoprotective, anti-asthmatic activities, immunomodulation, ant-viral and anti -bacterial besides its nutritional values.

Nutritional value of *Moringa oleifera*

Moringa oleifera is a nutrient-rich plant. Its leaves contain high amounts of minerals, Vitamins and beneficial organic compounds such as antioxidants. Minerals such as Ca, Na, Mg, Zn, Fe, Cu, Mn, Se, K, and P and Vitamins are A, E, and C and health-promoting phytochemicals: polyphenols, carotenoids, phytosterols and tocopherols, glucosinolates, folic acid, polyunsaturated fatty acids. According to the literature, there are more than 20 different pharmacologically active compounds found in Moringa Leaves.

Health benefits of *Moringa oleifera*

Dietary supplementation with *M. oleifera* leaves protect humans against iron deficiency and oxidative stress. Antioxidants, anticancer, antimicrobial, liver protectant, nerve protectant and liver metabolism are important phytochemicals found in these leaves.

Anti-microbial activity of *Moringa oleifera*

Use of antibiotics at large scale and in an irrational way have led to the emergence of antibiotic resistance in microbes. A wide range of plant extracts have been tested *in vitro* for their antimicrobial and antibacterial actions. For many years, herbal drugs have been prescribed for various ailments and in traditional medicines to cure varieties of infectious diseases. Herbal drugs are potent antibiotics and have potential to replace or reduce the load of synthetic antibiotics in the environment.

According to the studies conducted with the compounds, Thiocarbamate and Niaziminin which are isolated from the leaves of *M. oleifera* have been proven to have promising antiviral activity. Furthermore, the leaves of *M. oleifera* have shown potential to be used against HIV infections as the leaves immensely support the immunity of the patients.

Immunomodulation ability of leaf extract of Moringa

Moringa oleifera, a plant with various medicinal properties, exhibits immunomodulatory activity. Which means it can influence the body's immune system, potentially enhancing or modulating its responses.

The function of the immune system is to protect against infectious diseases and cancer. Many immunologists, oncologists, and other scientists have explored and elaborated and realized that the immune system as a target for developing therapeutic interventions. However, the immune system is highly regulated. As a result, there is a paradigm shift in the focus of many researchers on understanding the immune system's regulatory mechanisms and how these mechanisms can be modulated to target diseases.

Recently, interest in exploring the immunomodulatory effect of *Moringa oleifera* on the immune system becomes evident in scientific literature. For example, the anti-respiratory burst and anti-chemotactic properties of ethanol extract of *Moringa oleifera*'s Quercetin 3-O-glucoside, crypto-chlorogenic acid, and kaempferol 3-O-glucoside on neutrophils were reported. Therefore, Moringa oleifera leaves have a potential to be developed as immunomodulators that could cater for the general population, high-risk individuals and immunosuppressed patients.

Biodiesel /bioethanol production and water purification

M. oleifera seeds contain about 40% of oil potentially available for a wide range of applications, from food to cosmetics or biodiesel/bioethanol production.

Water extract of Moringa kernel has been shown to be useful for purification of water and wastewater, replacing coagulants for chemicals such as aluminum sulphate.

Furthermore, It has been proven that seeds of *Moringa oleifera* can remove heavy metal ions such as Pb and Cd at low concentrations, according to the studies conducted in Analytical laboratory of University of Peradeniya.

Toxicity studies of *Moringa Oleifera*

Moringa oleifera is generally considered safe when consumed in food or used as a short-term medicine, but high doses or prolonged use could potentially cause liver and kidney damage, and the bark may cause uterine contractions. Therefore, eating large amounts of moringa might be dangerous.

The study conducted an acute toxicity analysis in rats and reported genotoxic effects at a dose of 3000 mg/kg for 14 days while 1000 mg/kg was observed to be safe. However, some research studies reports that the safe level as 2000 mg/K.

Conclusion

Murunga oleifera plant grow in sub topical areas and native to India, also called "Miracle Plant" and "Tree of Life". Some Sri Lankan companies already import different products of this tree but mainly leaves in the powder form. However, Sri Lanka has not realized its potential fully as an export commodity to get foreign currency. This valuable plant is growing every part of Sri Lanka although it grows very well in arid regions like Jaffna. However, not much attention is paid by public about the value of this plant. Once people understand its nutritional, therapeutic and food values, more attention will be drawn by people. Furthermore, finding a medication for HIV from this plant is not very far away.

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Cover Page

Cover page shows a structure of perovskite-based solar cells. Perovskites hold promise for creating solar panels that could be easily deposited onto most surfaces, including flexible and textured ones. These materials would also be lightweight, cheap to produce, and as efficient as today's leading photovoltaic materials, which are mainly silicon. They're the subject of increasing research and investment, but companies looking to harness their potential do have to address some remaining hurdles before perovskite-based solar cells can be commercially competitive.

The term perovskite refers not to a specific material, like silicon or cadmium telluride, other leading contenders in the photovoltaic realm, but to a whole family of compounds. The perovskite family of solar materials is named for its structural similarity to a mineral called perovskite, which was discovered in 1839 and named after Russian mineralogist L.A. Perovski. For more details visit pages 32 - 35.

Cover photo from https://news.mit.edu/2022/perovskites-solar-cells-explained-0715.

Chemical Advances in Mosquito Repellents

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Mosquito-borne diseases, such as malaria, dengue, and Zika, continue to pose significant public health challenges worldwide, particularly in tropical and subtropical regions. The common types of mosquitoes present in the environment are as shown in Fig.1.

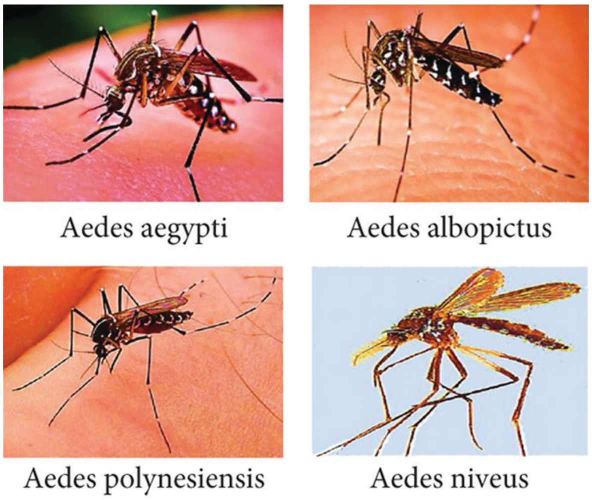


Figure 1. Most common types of mosquitoes in the environment

This review article delves into the intricate chemistry of mosquito repellents, offering a detailed examination of their molecular structures, mechanisms of action, and the latest advancements in repellent technologies. It explores synthetic pathways and the challenges in creating effective repellents, compares the stability and efficacy of natural versus synthetic compounds, and discusses the environmental impact and safety concerns associated with various repellent formulations.

The control of mosquito populations and the prevention of bites are critical in reducing the transmission of these pathogens. Chemical repellents have long been the primary means of protection against mosquito bites, with various synthetic and natural compounds developed to mitigate mosquito attraction. Despite the effectiveness of many conventional repellents, there remains a growing need for safer, more sustainable alternatives due to concerns about toxicity, environmental impact, and the development of resistance in mosquito populations.

Chemical composition of repellents

Mosquito repellents typically contain a range of active chemical ingredients that disrupt the host-seeking behavior of mosquitoes. DEET, N,N-diethyl-meta-toluamide, (**1**) shown in Fig. 2 remains one of the most widely used synthetic compounds due to its broad efficacy and prolonged protection time [1].

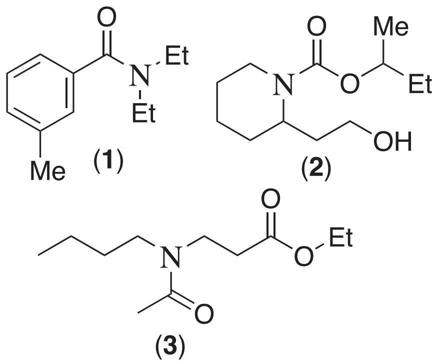


Figure 2. Structures of DEET (**1**), picaridin (**2**) and IR3535 (**3**)

Studies suggest that (**1**) works by confusing the olfactory receptors of mosquitoes, making it difficult for them to locate a host [1,2]. Other commonly used synthetic compounds include Picaridin or Icaridin (**2**), known for its lower skin irritability and comparable efficacy to DEET, and IR3535, ethyl butylacetylaminopropionate, (**3**) which has shown similar results with less persistence on the skin [3]. Increasingly, natural repellents such as citronella, lemongrass oil, eucalyptus oil, and neem oil are incorporated into formulations due to their mosquito-repelling properties and lower toxicological profiles [4]. The active compounds in these essential oils - like citronellal, eucalyptol, and linalool - act on the mosquito's olfactory and sensory neurons to produce a repellent effect [5]. However, these natural products typically require higher concentrations and more frequent application than synthetic repellents, as they tend to evaporate quickly and provide shorter protection durations [3].

Formulation chemistry

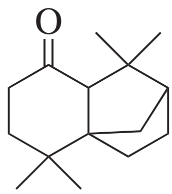
The formulation chemistry of mosquito repellents focuses on optimizing the delivery, stability, and efficacy of active repellent ingredients. Emulsions, aerosols, lotions, gels, and sprays are among the most common formulations, each requiring different chemical considerations to ensure effective release and prolonged action of the active compounds, such as DEET and essential oils [1]. The stability of these active ingredients is a critical factor, as they must remain effective under varying environmental conditions, particularly temperature and humidity. Solvents and carriers, such as alcohol or cyclomethicone, are often included to improve solubility, facilitate even distribution, and enhance skin absorption without causing irritation [2]. Emulsifiers and stabilizers like lecithin and glyceryl stearate are used to create uniform mixtures, especially in water-based formulations, improving consistency and ease of application [3].

Encapsulation techniques, such as microencapsulation and nano-emulsion, have also been explored to provide controlled release of repellents over time, increasing the duration of mosquito protection while minimizing the evaporation of volatile components like essential oils [4,5]. Such advanced formulation strategies help in balancing potency, longevity, and user comfort, making repellents more convenient and effective for consumers.

Figure 3. Some mosquito repellents available in the market

Synthesis of repellent molecules

The synthesis of mosquito repellent molecules typically aims to enhance the activity, stability, and compatibility of these compounds in various formulations. DEET (**1**), the most common synthetic repellent, is synthesized through the acylation of meta-toluic acid with diethylamine, forming an amide linkage that helps block mosquito olfactory responses to human skin odors [1]. Another synthetic repellent, Picaridin (**2**), is derived from the piperidine ring, involving a multistep process that introduces a hydroxyethyl side chain, which provides both long-lasting efficacy and low skin irritation [2]. IR3535 (**3**), an ester-based repellent inspired by the natural amino acid structure of beta-alanine, is synthesized by combining an amino acid backbone with an ester linkage, resulting in a compound that is effective yet environmentally benign [3]. Recent research has focused on semi-synthetic methods to produce terpene-based repellents, such as isolongifolanone (**4**) (Fig. 4), which is derived from natural sources like pine oil through processes like catalytic hydrogenation. This semi-synthetic approach reduces the environmental footprint while retaining effective mosquito-repelling properties [4,5]. The structural diversity in these synthetic molecules allows for a range of functional groups and linkages, which are designed to interfere with the sensory receptors of mosquitoes in various ways, enhancing overall repellent performance.



(4)

Figure 4. Structure of isolongifolanone (4)

Natural vs synthetic repellents

Table 1 demonstrates the key aspects of natural and synthetic mosquito repellents, including efficacy, duration, safety, and environmental impact.

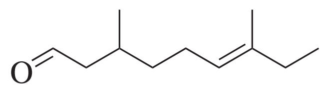
Table 1. Comparison of natural and synthetic repellents

Aspect [References]	Natural Repellents	Synthetic Repellents
Examples [1-4]	Citronella, Eucalyptus oil, Neem oil	DEET, Picaridin, IR3535
Efficacy [1-2]	Effective but generally lower than synthetic repellents	Highly effective with consistent protection
Duration [2,5]	Shorter protection time; requires frequent reapplication	Long-lasting, providing several hours of protection
Mode of Action [1,4,5]	Masks human odors, deterring mosquitoes	Blocks mosquito olfactory receptors from detecting skin odors
Skin Safety [3,4]	Generally safer, lower irritation risk	May cause skin irritation (DEET); Picaridin is gentler
Environmental Impact [1,3]	Biodegradable & ecofriendly	Persistent in environment, may impact water sources (DEET)
Cost [2,4]	Often lower; widely available	Generally, more expensive to produce
Volatility [3,5]	High volatility, tends to evaporate quickly	Lower volatility, especially with formulations like Picaridin

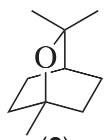
Chemical sensing and mosquito behavior

Mosquitoes rely on highly sensitive chemical sensing mechanisms to locate human hosts, with specific olfactory receptors in their antennae that detect carbon dioxide, body heat, and skin odors. These receptors play a crucial role in enabling mosquitoes to sense and target certain compounds, such as lactic acid and other volatiles, which are characteristic of human scent [6]. Repellents like DEET interfere with these olfactory receptors, masking the human scent or creating confusing signals that disrupt the mosquito's ability to detect and approach a host [7]. Studies have shown that DEET binds to certain odorant receptors, reducing the attraction of mosquitoes to skin odors, while other repellents, such as citronella (**5**) and eucalyptol (**6**), create a temporary barrier by overwhelming the mosquitoes' olfactory systems with strong, volatile compounds [8].

The structures of citronellal (**5**) present in citronella oil and eucalyptol (**6**) present in eucalyptus oil are shown in Fig. 5.



(**5**)



(**6**)

Figure 5. Structures of citronellal (**5**) and eucalyptol (**6**)

Picaridin, a synthetic repellent, also affects olfactory signaling by inhibiting receptors that are involved in recognizing human-derived odor cues [9]. These molecular interactions with olfactory receptors significantly influence mosquito behavior, reducing the likelihood of mosquito bites and thereby playing a critical role in the efficacy of repellents [10].

Resistance and adaptation

Over time, mosquitoes have shown the ability to adapt to various chemical repellents, potentially leading to decreased efficacy and even resistance.

Studies indicate that prolonged exposure to repellents like DEET may induce changes in mosquito behavior and physiology, allowing them to bypass or tolerate the repellent's effects. For instance, Aedes aegypti mosquitoes have been observed to reduce their avoidance response to DEET after repeated exposure, suggesting a form of desensitization to its active compounds [11]. Additionally, genetic studies reveal that certain mosquito populations may develop mutations in their olfactory receptors, which alter their sensitivity to chemical repellents, thus enabling these mosquitoes to detect human odors despite the presence of repellents [12]. Cross-resistance is also a concern, as adaptation to one repellent could reduce sensitivity to other related compounds. For example, mosquitoes exposed frequently to DEET may also exhibit reduced avoidance to structurally similar repellents like Picaridin [13]. This growing evidence underscores the need for continuous research to develop novel repellent formulations that can counteract potential resistance mechanisms and remain effective in mosquito control [14,15].

Safety and toxicology

The safety and toxicological effects of mosquito repellents are critical considerations, especially given their widespread use for personal protection against vector-borne diseases. Synthetic repellents like DEET and Picaridin have been extensively studied and are generally considered safe for use when applied according to guidelines; however, they are not without potential risks. DEET, for example, is highly effective but has been associated with skin irritation, neurotoxicity in rare cases, and potential environmental persistence, raising concerns for both human health and ecosystems [16]. Although typically rare, neurotoxic effects have been reported in cases of over-application or accidental ingestion, particularly in children [17]. Picaridin is known to be less irritating to the skin and has a lower toxicity profile, making it a preferable alternative for some users, but it still carries a risk of mild side effects [18]. Natural repellents, such as citronella and eucalyptus oils, are perceived as safer and are less likely to cause skin irritation, yet their safety profile is complicated by their high volatility, which can lead to eye or respiratory irritation with overuse [19]. Evaluating the balance between efficacy and safety remains crucial for repellent selection, as higher concentration formulations, regardless of repellent type, generally increase the risk of adverse effects [20].

Environmental impacts of repellent chemicals

The environmental impact of mosquito repellent chemicals is an important concern, especially with widespread usage in areas affected by vector-borne diseases. Synthetic repellents like DEET and Picaridin, though effective, have been shown to persist in the environment, posing risks to aquatic ecosystems. Studies indicate that DEET can contaminate water sources, with detectable residues found in freshwater environments, potentially affecting aquatic organisms such as fish and amphibians [21]. The compound has been shown to be toxic to certain species, disrupting their behavior and reproductive systems [22]. Similarly, while Picaridin is considered less persistent than DEET, it can still accumulate in water and soil, raising concerns over its long-term environmental effects [23]. On the other hand, natural repellents like citronella and eucalyptus oil, though biodegradable, still pose risks due to their high volatility and potential for air and water pollution when used in large quantities. Citronella, in particular, can contribute to air pollution in confined spaces and cause respiratory irritation in sensitive individuals [3]. Understanding and mitigating the environmental impacts of repellent chemicals remains essential for ensuring that their benefits in controlling mosquito populations do not come at a greater ecological cost [24].

Conclusion

In conclusion, mosquito repellents play a crucial role in reducing the spread of vector-borne diseases by effectively preventing mosquito bites. Both synthetic and natural repellents have been developed and extensively studied for their efficacy and safety. While synthetic repellents such as DEET and Picaridin have proven to be highly effective, their environmental impact and potential for resistance in mosquito populations raise important concerns that warrant ongoing research. Natural repellents, though generally considered safer for both humans and the environment, often have limited duration and efficacy. The development of new repellent formulations, including those that combine natural and synthetic ingredients, holds promise for enhancing efficacy while minimizing adverse effects. Furthermore, a better understanding of the chemical interactions between repellents and mosquito behavior, as well as their environmental impacts, is essential for optimizing their use. Ultimately, balancing the need for effective mosquito control with environmental and safety considerations will be key to developing sustainable, long-term solutions for vector management. Continued innovation and research into alternative repellents and resistance management strategies are necessary to ensure that these products remain effective in the fight against mosquito-borne diseases.

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Guest Articles

Phytochemical constituents and medicinal uses of *Aloe vera*

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Introduction

Aloe vera or *Aloe barbadensis* miller is a well-known perennial xerophyte which belongs to Liliaceae family. In Arabic, "Aloe" refers to "shining bitter substances," while in Latin, "Vera" means "true." Moreover, this plant is commonly known by other names such as Kumari, Burns Plant, Lily of the Desert, and Elephant's Gall. The habitat of this plant ranges from tropical to subtropical regions, with the ability to withstand high temperatures up to 40 °C. The most significant feature of this plant is its gel encased by the rind the outer layer of the leaf. This gel is rich in phytochemicals such as flavonoids, anthraquinones, polyphenols, phytosterols, chromones, *etc*. Many of them possess advanced medicinal properties used to treat conditions such as anti-diabetic, anticancer, anti-microbial, antiviral, antioxidant, antiseptic, anti-inflammatory, anti-aging, hormone modulatory, and wound healing.

Aloe vera is used in the cosmetic industry (as sunscreen, body lotion, shampoo, moisturizing cream, haircare product, *etc*.), food and pharmaceutical industry (*e.g*., drink, powder, pill, food preservative, *etc*.) (Fig. 1). In Asia and the US, *Aloe vera* is added to dairy products such as ice cream and milk, not only for flavoring but also as a food preservative. In South Africa, people consume *Aloe vera* gel as food. During cheese production, the gel is added to create a prebiotic food.

Figure 1: Products of *Aloe vera*

Morphology

Aloe vera (Fig. 2) is one of the plant species that consists of crassulacean acid metabolism mechanism, (*i.e*., a special pathway of carbon fixation that allows them to grow under water stress conditions). The height of this cactus-like plant is 60-90 cm. Around 100-200 bisexual (or hermaphroditic) yellow-colored tubular flowers of *Aloe vera* are helically arranged as a cluster on an erected spike as shown in Fig. 3. The length of this spike is about 90-100 cm.

Figure 2: *Aloe vera* plant

Figure 3: The matured inflorescence of *Aloe vera*

The leaf of *Aloe vera* can be divided into several layers such as rind (A), latex (B) and gel (C) as shown in Fig. 4.

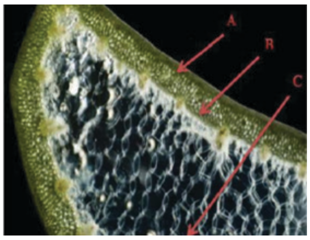

Figure 4: The light microscopic view of cross section of *Aloe vera* leaf.

The rind is the outermost protection layer which contains about 15-20 cells, and it helps in carbohydrates and protein synthesis. Yellow color bitter taste latex can be seen between the rind and the gel. The main constituents of the latex are anthraquinones and glycosides. Soft, clear, moist, transparent semi-solid gel is made up from a large parenchyma cell and 99% of it consists of water. *Aloe vera* powder and essential oil used mainly in cosmetic industry are manufactured using this gel.

Phytochemicals in *Aloe vera*

This plant contains various bioactive compounds, such as polyphenols, flavonoids, alkaloids, carotenoids, phytosterols, saponins, and tannins, which function as phytochemicals.

The leaf contains more than 30 **anthraquinones** (*i.e.*, large structural variety of compounds among the polyketide group). Aloin A **1a** and aloin B **1b** are the most abundant compounds in this plant. Chrysophanol **2**, emodin **3**, physcione **4**, aloe-emodin **5** are other foremost anthraquinone derivatives present in it. The structures of some anthraquinones and their derivatives present in *Aloe vera* are given in Table 1 and Fig. 5.

Table 1: Some anthraquinones and their derivatives present in *Aloe vera*

Compound name	No.
Aloin A	**1a**
Aloin B	**1b**
Chrysophanol	**2**
Emodin	**3**
Physcione	**4**
Aloe-emodin	**5**
6'-O-Acetyl-aloin A	**6a**
6'-O-Acetyl-aloin B	**6b**
10-Hydroxyaloins A	**7a**
10-Hydroxyaloins B	**7b**
Aloinoside A	**8a**
Aloinoside B	**8b**
7-Hydroxyaloin A	**9a**
7-Hydroxyaloin B	**9b**
7-Hydroxy-8-O-methylaloin A	**10a**
7-Hydroxy-8-O-methylaloin B	**10b**
6'-malonylnataloin A	**11a**
6'-malonylnataloin B	**11b**
Homonataloside B	**12**
Elgonica dimer A	**13a**
Elgonica dimer B	**13b**
Aloindimer A-D	**14a-d**
Madagascine	**15**
Rhein	**16**

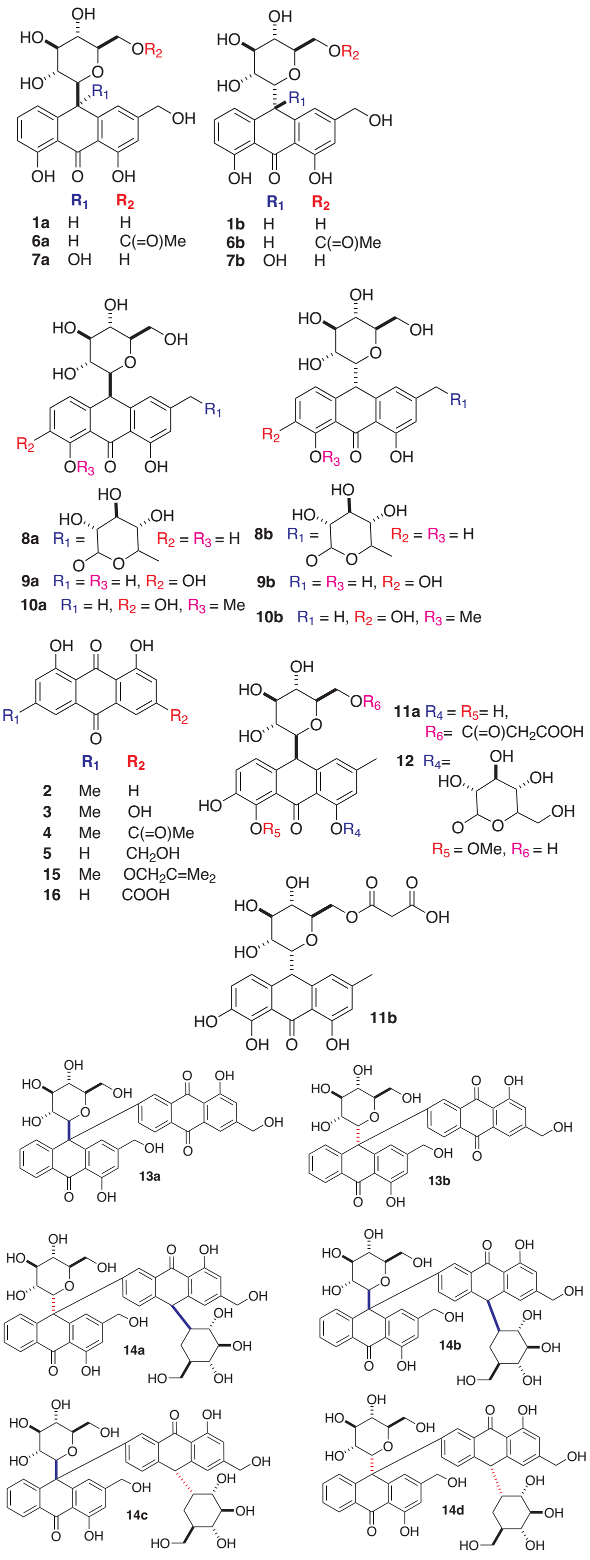

Figure 5: Structures of some anthraquinones and their derivatives

Chromones are a group of chemical compounds containing 5:6 benz-1:4-pyrone rings. Most prominent chromones present in *Aloe vera* are aloeresin A **17**, aloeresin B/aloesin **18**, isoaloeresin D **19** and aloeresin E **20**. Some of the chromones which are present in this plant are given in Table 2 and the structures are given in Figure 6.

Table 2: Some of the chromones present in this plant

Name	No.
Aloeresin A	**17**
Aloeresin B/aloesin	**18**
Isoaloeresin D	**19**
Aloeresin E	**20**
Neoaloesin A	**21**
Aloeverasіde A	**22a**
Aloeverasіde B	**22b**
6’-O-coumaroyl-aloesin	**23**
Allo-aloeresin D	**24**

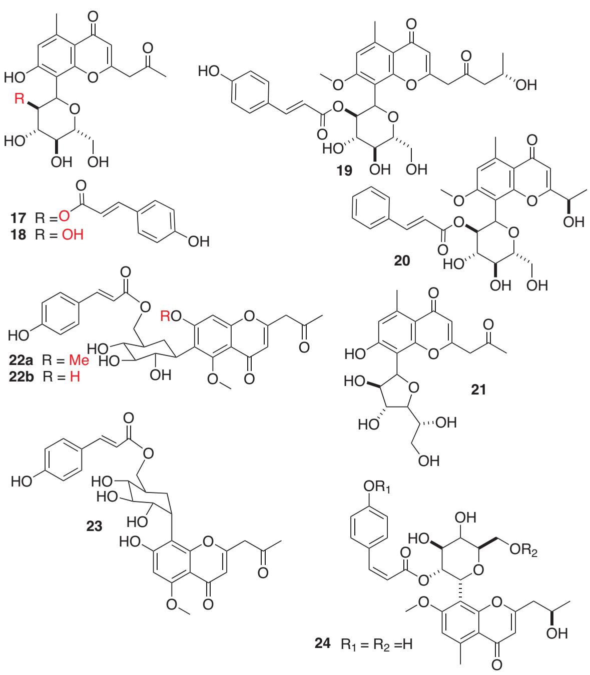

Figure 6: Structures of some anthraquinones and their derivatives

Apigenin **25**, kaempferol **26,** quercetin **27**, epicatechin **28**, D-catechin **29**, rutin **30**, and luteolin **31** are some of the flavonoids present in *Aloe vera* plant. Polyphenols such as chlorogenic acid **32**, caffeic acid **33**, caffeoyl shikimic acid **34**, gallic acid **35**, *p*-coumaric acid **36**, coumarin **37** give immense medicinal value to the plant. Cycloartenol, lophenol, 24-ethyl-lophenol, 24-methyllophenol, and 24-methylene-cycloartanol are

phytosterols found in the gel.

Health benefits of *Aloe vera*

Aloin acts on skin and reacts against pimples. Flavonoids and polyphenols slow down the aging process while acting as antioxidants. Proline, an amino acid present in the gel, helps maintain the elasticity of the epithelial tissues in the skin. Anthraquinones in *Aloe vera* gel enhances gastrointestinal motility and the gel gives laxative effect.

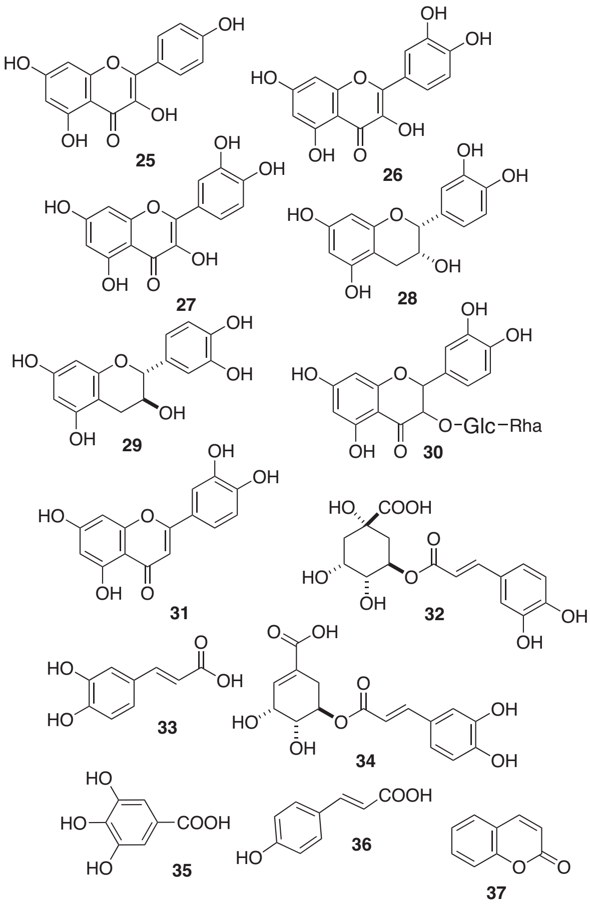

Figure 7: Some of the flavonoids and polyphenols present in *Aloe vera*

These compounds in the *Aloe vera* improve the functions of gastrointestinal system by stimulating colonic mobility, increasing electrolyte and fluid transport and accelerating the intestinal transit rate. Leaf extract of *Aloe vera* improves the transportation of poorly absorbed drugs through membranes. Thus, it can enhance the bio availability of the drugs by orally using. Lutein, acemannan, and aloe emodin present in the gel, improve the immunity of the body as well as gives a good vision.

Aloe vera shows anti-microbial properties. Inhibition of solute transport through membranes of bacteria (such as *B. subtilis*, *E. coli*, *S. epidermidis*, and *S. sonnei*) is occurred by polyphenolic compounds present in this plant. Not only bacteria, but also fungi species such as *D. hawaiensis* and *A. alternate* are completely inhibited by *Aloe vera*. Lupeol, salicylic acid, urea nitrogen, phenols and sulphur in this plant are antiseptic agents which inhibit fungi, bacteria and viruses. Aloe emodin and aloesin disrupt the bacterial membrane. Cinnamic acid, coumaric acid, ascorbic acid and pyrocatechol are acted against gram positive bacteria. β-sitosterol prevents the entry of the virus into the host cell.

Researchers found that *Aloe vera* gel consists of higher antioxidant value compared to those of pure alpha-tocopherol and butylated hydroxytoluene. Flowers of this plant have more bioactive compounds than the leaf. Gentisic acid present in flowers contains not only antioxidant properties, but also anti-inflammatory and anti-rheumatic properties. β-sitosterol is used as a treatment for breast cancer and diabetes. Sitosterol present in the leaf gel is used to treat enlarged bladder and it lowers the cardiovascular risk as well as prevents cancers. Aloe emodin acts as anti-cancer agent and inhibits lipid peroxidation. Furthermore, *Aloe vera* can be used to treat infertility and Polycystic ovary syndrome (PCOS).

According to the International *Aloe* Committee of Science Standards (IACSS) recommendations, the maximum limit of *Aloe vera* juice content in oral administration is less than 10 mg/kg, and less than 50 mg/kg for non-medicinal uses. However, prolonged or high dose consumption of *Aloe vera* can be a reason for imbalance of electrolysis in the body. *Aloe vera* is not recommended for oral use of pregnant and lactating mothers, infants and the people who suffering from abdominal pain, appendicitis and intestinal obstructions.

Conclusions

Aloe vera is a succulent plant widely recognized for its medicinal properties. Its gel contains various classes of phytochemicals, including polyphenols, flavonoids, alkaloids, carotenoids, phytosterols, saponins, tannins, and more. These bioactive compounds are used to treat a broad range of ailments, offering antidiabetic, anticancer, antimicrobial, antiviral, antioxidant, antiseptic, anti-inflammatory, anti-aging, and wound-healing benefits. Moreover, *Aloe vera* serves as a key ingredient in the nutraceutical, pharmaceutical, and cosmeceutical industries due to its versatile therapeutic potential.

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Guest Articles

3D Printed Eco-Friendly Acoustic Panels

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Introduction

Sound pollution, one of the current environmental issues, arises from myriad sources ranging from traffic, construction, and industrial activities to aircraft/spacecraft, loud music, and other household appliances. As per the World Health Organization (WHO) standards, sound waves above 65 decibels (dB) are considered as polluted noise. Researchers have utilized many types of acoustic materials such as mineral wool, synthetic fibres, and polymer foams, especially in the building and construction industry. However, these conventional materials could act as health hazards to humans and their solid waste contributed to environmental pollution (Qui et al. 2018). Herein we report the preparation and acoustic performance of two novel composites using pineapple leaf fibres (PALF) and water hyacinth fibres (WHF) with polylactic acid (PLA).

Over the past few years, PALFs and WHFs have been studied on sound adsorption applications due to their unique characteristics such as high cellulose fiber content, porosity, readily availability, low-cost, and environment-benignity (Putra et al. 2018; Sukhawipat et al. 2022). Polylactic acids (PLAs), also known as synthetic biopolymers or bioplastics, have recently been considered for fabricating thermoplastic filaments in 3D printing due to their low melting range, high strength, low thermal expansion, and better layer-adhesion (Yang et al 2014; Appuhamillage et al. 2018).

To the best of our knowledge, this work represents the first mechanically robust, 3D-printed acoustic panels that achieve the maximum sound absorption coefficient (α-max) > 0.5 with relatively low fiber loading. Most importantly, these panels are effective within the high-frequency sound range of 2,000 to 20,000 Hz. Our innovative approach paves the way for future developments of low-cost acoustic devices as a solution against noise pollution associated with high frequencies. Moreover, the current study provides a sustainable solution for mitigating the notorious aquatic weed, Eichhornia crassipes (water hyacinth).

Materials and Methods

PLA (Luminy LX175) in fine resin pellet form (melt flow index-MFI at 190 °C/2.16 kg) was received from Natur Tec Lanka (Pvt) Ltd, Sapugaskanda, Sri Lanka. Water hyacinth (WH) plants were obtained from Wedaru Lake in Kurunegala, Sri Lanka. Pineapple plant leaves were collected from a pineapple fruit farm at Avissawella, Sri Lanka. Sodium hydroxide (NaOH) and sodium hypochlorite (NaOCl) powders were purchased from Glorchem Enterprises, Colombo 11, Sri Lanka.

Extraction of fibers

The fresh WH stems were first separated from the roots and other parts of the plant. Then, the WH stems were cleaned to remove dust and ash and immersed in water for 5 days to soak. Separated WHFs were then sun-dried for another 15 days to remove water and then mechanically crushed. On the other hand, the collected PALs were fed into a decorticator/defibering machine, and PALFs were extracted directly. Finally, these PALFs were sun-dried for 8 hours and mechanically crushed using a cutting mill (SM300-Rostfrei).

Chemical treatments

In order to remove the hemicellulose, lignin, proteins, pigments, other impurities, and amorphous fractions, both alkaline (using 5 wt. % of NaOH solution) and bleach (using 1.5 wt.% of NaOCl solution) treatments were performed on WHFs and PALFs. Removal of impurities upon treatments reduces the diameter of fibers having high surface area pore networks. Oscillating air molecules of incident sound waves loss their momentum via friction inside these high surface area pores, thereby improving acoustic properties (Samaei et al. 2020).

Preparation of composites

Above chemically treated fibers were further dried in oven at 105 °C until a constant weight and then subjected to mechanical crushing to yield powders of 250 microns particle size. These finely ground WHFs and PALFs were separately subjected to homogenous mechanical mixing with PLA, according to Table 1.

Table 1. Composition of the composites in wt.%.

Material	PLA (wt.%)	WHF (wt.%)	PALF (wt.%)
Control (neat PLA)	100	0	0
1WHF/PLA	99	1	0
5WHF/PLA	95	5	0
7WHF/PLA	93	7	0
10WHF/PLA	90	10	0
1PALF/PLA	99	0	1
5PALF/PLA	95	0	5
7PALF/PLA	93	0	7
10PALF/PLA	90	0	10

After that, each fine mixture was separately introduced into a mould (200 mm (length) × 200 mm (width) × 1 mm (thickness)) of a heat-press machine ZLCB5-2, and the composites were prepared at 200 °C for 4 min under 2 MPa pressure. After cooling for 15 min the composites were removed from the mould.

Thermal characterization

As-prepared composites and neat PLA (the control) were subjected to TGA analysis using the TG analyzer (TGA 5500- Discovery TA) at 30-700 °C under a nitrogen atmosphere and at a 10 °C/min heating rate. DSC analysis was also performed using a DSC Q100-TA instrument in the 30-300 °C temperature range at a heating and cooling rate of 10 °C/min.

Fourier transform infrared (FTIR) spectroscopic analysis

FTIR analysis was performed using an FTIR-6100-JASCO spectrometer in the 4000 - 500 cm^{-1} range at a resolution of 2 cm^{-1} and 16 scans. Transmission mode was used with JASCO's exclusive Spectra Manager TM II cross-platform software. All FTIR samples were prepared using KBr pellets.

Testing physico-mechanical properties

Density, hardness, tensile, and impact strength tests were also performed following the relevant standard test methods.

Acoustic property measurements

The sound absorption coefficient (α) was calculated for the composites in the 500 -5,000 Hz frequency range using a standard impedance tube, following the ISO 10534-2 standards ("ISO 10534-2 (1998-11)"). Disc-shaped samples (panels) with 5 cm diameter and 1 mm thickness were used for testing. Neat PLA was used as the control. Triplicate readings were taken from each sample for a particular sound frequency (Hz). Average α values have been plotted vs. sound frequency (Hz).

3D printing

First, the 3D printable filaments were prepared using a laboratory developed technique as described in Wijekoon et al. 2024. The composites 1WHF/PLA, 1PALF/PLA, and neat PLA, the control, were 3D printed into disc-shaped panels of 5 cm diameter and 1 mm thickness using a 3D printer (Creality-Ender 3). All the 3D printing parameters were in accordance with those reported in Wijekoon et al. 2024.

Post-printed testings

Acoustic property, tensile strength, and toughness measurements were also taken for the as-printed panels. SEM analysis was also performed to detect the distribution of pores.

Results and Discussion

In this section, results of 3D printing, post-printed acoustic, tensile, toughness, and SEM analysis are discussed. Figure 1 denotes the successfully 3D printed acoustic panels.

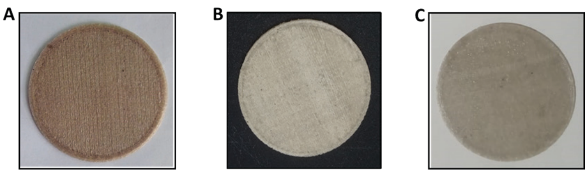

Figure 1: 3D-printed acoustic panel of 1 WHF/PLA (A), 1 PALF/PLA (B), and neat PLA (C). Adapted from Wijekoon et al. 2024.

Figure 2 illustrates the resulting absorption coefficient (α) values against sound frequency for the 3D printed panels. Both WHF/PLA and PALF/PLA composites demonstrated α-Max > 0.5 in the high sound range (2,000-20,000 Hz) with only 1 wt% cellulosic fiber loading. Contrary to previous studies reported in the literature, our results show a significant potential for improving the acoustic properties of 3D-printed composites with minimal fiber content. Moreover, the porosity of the composites is only contributed by cellulose fibers, and there are no effects of drilling methods and 3D printing on the porosity.

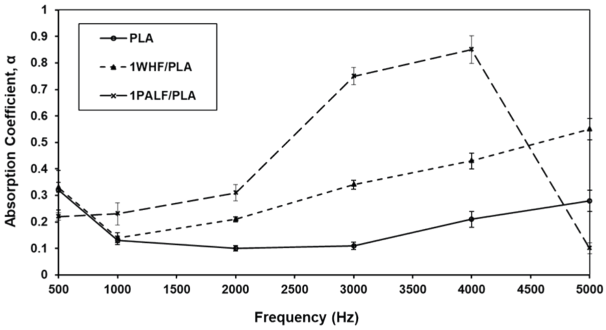

Figure 2: Variation of α with increasing sound frequency (Hz) for the 3D-printed acoustic panels of 1 WHF/PLA, 1 PALF/PLA, and neat PLA (sample thickness is 1 mm). t-Tests demonstrate a statistical significance of $p < 0.05$ for the α values of 1 WHF/PLA vs. PLA and those of 1 PALF/PLA vs. PLA, obtained at 2000, 3000, 4000, and 5000 Hz. Adapted from Wijekoon et al. 2024.

Figure 3 demonstrates the post-printed tensile and toughness properties of the panels.

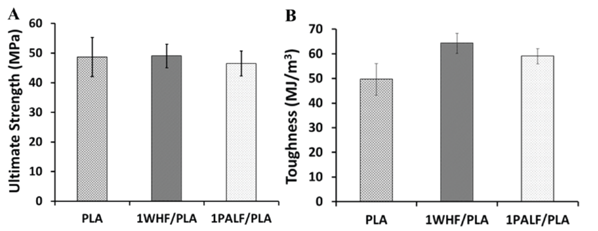

Figure 3: Tensile strength of 3D-printed ASTM D638-type V standard tensile specimens of 3D printed panels (A). t-Tests demonstrate no statistical significance of $p > 0.05$ for these measurements. Toughness values of such 3D-printed panels (B). t-Tests demonstrate a statistical significance of $p < 0.05$ for the toughness values of 1 WHF/PLA vs. PLA and those of 1 PALF/PLA vs. PLA. Adapted from Wijekoon et al. 2024.

Figure 4 denotes the surface and cross-sectional SEM images obtained for the 3D printed panels.

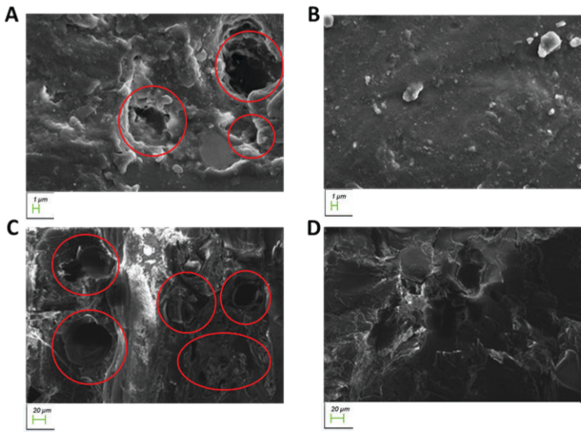

Figure 4: Scanning Electron Microscopic (SEM) images of the 3D-printed 1 WHF/PLA panel and neat PLA. Surface SEM images of 1 WHF/PLA (**A**) and neat PLA (**B**) obtained using 5000 × magnification. Cross-sectional SEM images of 1 WHF/PLA (**C**) and neat PLA (**D**) obtained using 500 × magnification. Pores have been circled in red. Adapted from Wijekoon et al. 2024.

Conclusions and future work

In conclusion, the work reported here introduced the easy preparation of composites with natural cellulosic fibers of WH and PAL with PLA. For the first time, the FFF-based AM of these materials has yielded mechanically robust and sustainable composite acoustic panels that showed the best performance within the high-frequency sound range at a low fiber loading of 1 wt %. The 3D-printed 1 WHF/PLA panel achieved α-max of 0.55 at 5,000 Hz, while the printed 1 PALF/PLA panel showed its best acoustic performance of α-max of 0.83 at 4,000 Hz. Moreover, the resulting tensile strength of the 3D-printed panels is approximately three-fold higher than the non-3D-printed versions and significantly higher than many commercial acoustic absorbers. These low-cost and environmentally friendly 3D-printed composite panels can be used as green engineering materials to construct walls and ceilings to negate high-frequency noises. Importantly, this study also provides a sustainable solution for aquatic weeds, such as water hyacinth (WH), by utilizing them to produce sound absorbers.

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Role of carbon in photocatalysis

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Photocatalysis is the phenomenon in which the rate of a chemical reaction increases in the presence of light as the energy source and a substrate that absorbs light, commonly called a photocatalyst, which is primarily a semiconductor. The photocatalyst generates electron-hole pairs at exposure to light, where an electron generated at the valence band is excited to the conduction band, leaving a hole at the valence band. These charge carriers are responsible for producing oxygen-rich radicals such as $OH^{\bullet}$ and $O_2^{-\bullet}$, which would degrade the pollutants in water. Semiconductors being used either individually, including TiO_2, ZnO, WO_3, Fe_2O_3, CuO *etc*., or semiconductors like TiO_2 and ZnO, which are UV sensitive, are doped with metals like Fe, Cu, Co, Ni and non-metals like N, C, and S or in general semiconductors are coupled with other semiconductors to improve the efficiency of photocatalysis [1–3]. Interestingly, semiconductors have been decorated widely with carbon-related materials to enhance activity. This article summarizes a few such recent findings.

Graphene oxide and Reduced Graphene Oxide

Graphene oxide (GO) is synthesized using Hummer's method using graphite as the starting material. Sri Lanka is well-known worldwide for its purest graphite, Ceylon graphite, and converting it to graphene oxide, which could be used in many applications, would be a valuable addition. Oxygen-rich functional groups such as COOH, OH and lactones are created on the carbon surface during the conversion of graphite to graphene oxide. Graphene oxide could be further reduced to form reduced Graphene oxide (rGO). Both graphene oxide and reduced graphene oxide are coupled with semiconductors to enhance their photocatalytic activity. The photocatalytic activity of CoO_X/MnO_X has been enhanced by coupling with GO [4]. GO acts as an adsorbent, which adsorbs methylene blue via the functional groups present on the surface. Hence, the proximity of the reactant molecule to the surface of the catalyst where the radicals are generated is increased, enhancing the catalytic activity. Further, the main drawback of semiconductors being used as photocatalysts is the high electron-hole pair recombination rate. The conductive surface of GO enhances the separation of the charge carriers and improves the photocatalytic activity. The TiO_2/CuO system monitored the same behaviour when the coupled semiconductors were further decorated with GO and rGO [5]. Moreover, iron and titanium-based semiconductors, Fe_2O_3/Fe_2TiO_5, synthesized using ilmenite sand as the raw material, were also coupled with GO and rGO, where a significant enhancement in the photocatalytic activity was observed [6].

Graphitic carbon nitride

Unlike other carbon sources, graphitic carbon nitride (g-C_3N_4) is a semiconductor that can be used as a metal-free semiconductor in photocatalysis. The stable structure of g-C_3N_4 contains periodically linked tris-s-triazine units, and the structure is quite similar to that of graphite, where N atoms replace some of the carbon atoms. The sp^2 hybridized C and N undergo π conjugation in the graphitic planes. The nitrogen lone pair significantly impacts the material's electrical characteristics, mainly contributing to the valance band. g-C_3N_4 coupled with TiO_2/Cu doped TiO_2 formed a heterojunction with type II band alignment, enhancing the charge separation and increasing the photocatalytic activity [7]. g-C_3N_4, in couple with Fe_2O_3 and Fe_2TiO_5, formed a dual z-scheme, improving the charge separation and photocatalytic performance, as shown in Figure 1[8].

Catalytically graphitized carbon

Amorphous carbon sources can be catalytically graphitized in the presence of metal catalysts and pyrolyzing the carbon samples at elevated temperatures like 800 °C. Such carbon turned out to be turbostratic carbon, which is a form of crystalline carbon whose carbon layer arrangement is quite similar to that of graphite, with minor changes, especially in the band gap, where in graphite, it should be 0.335 nm and that of turbostratic is a little larger than that ranging ~ 0.34 nm. Catalytically graphitized carbon enhances dye adsorption, charge separation, and migration by providing a conductive matrix. Catalytically graphitized carbon originated from sugar coupled with Fe_2O_3 [9], TiO_2-Fe_3C-Fe-Fe_3O_4 [10], and carbon derived from shrimp shells coupling with TiO_2-Fe_2O_3-Fe showed higher photocatalytic activity [11]. Figure 2 illustrates the semiconductor arrangement on catalytically graphitized carbon and their affect on methylene blue photodegradation.

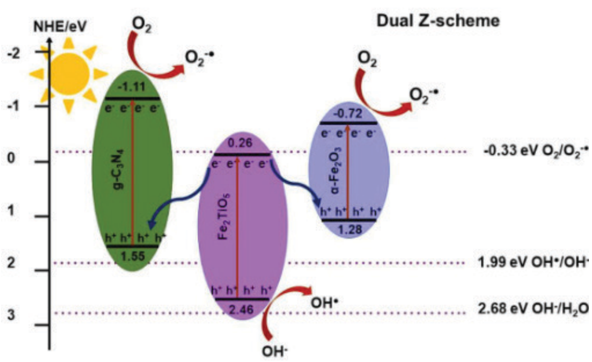

Figure 1. Band alignment of the synthesized nanocomposite showing a Dual Z-scheme. Figure adapted from reference [8].

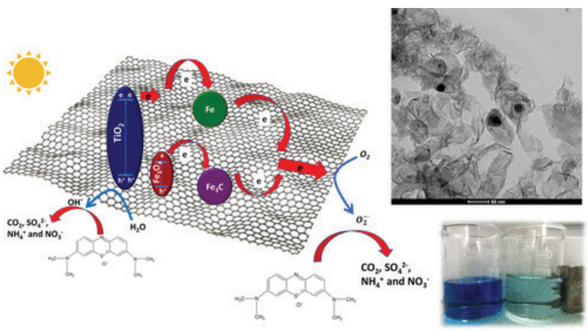

Figure 2. Semiconductors supported on catalytically graphitized carbon and use of them in photodegrading methylene blue. Figure adapted from reference 11.

Therefore, it is evident that carbon plays a crucial role in photocatalysis, and the use of natural sources to derive the carbon of interest would be a value addition that can be used either for environmental remediation or green energy production.

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Guest Articles

Microplastics: A Growing Threat to Agricultural Ecosystem

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Introduction

Over the past decades, the demand for plastic products has increased drastically due to their low cost and durability. Also, plastics are used in a wide range of applications across various industries, including packaging, construction, healthcare, textiles, agriculture and more. These plastic materials possess a strong physical structure and complex chemical properties (Monkul and Ozhan, 2021), enabling them to persist in the environment for long periods. This persistent nature raises concerns about their long-term impacts on soil, plant health, and broader environmental issues, particularly when these plastics degrade into microplastics and release plastic additives. Understanding these impacts is crucial for developing environmental sustainability as well as improving agriculture productivity.

According to Bui *et al*. (2020), the amount of plastic produced worldwide has increased tremendously, from 1.5 million tonnes to about 359 million tonnes over the past 70 years and this quantity is expected to double by 2050 (Monkul and Ozhan, 2021). Drzyzga and Prieto (2019) reported that in 2016, 27.1 million metric tons of plastic wastes were collected in the European Union (EU) and 31.1 % were recycled, 41.6% were used for energy recovery, and the remaining 27.3% was disposed of at landfill sites.

The interest of using plastics in agriculture is rapidly increasing as the population growth places a significant pressure on global food production. The use of plastics in agriculture is known as the plasticulture (Lalitha *et al*., 2010), which comprises various practices aimed at improving crop production and efficiency. Therefore, modern agriculture widely uses plasticulture techniques to mitigate environmental risks and increase the crop production. (Lalitha *et al*., 2010).

Polythene, polypropylene, polystyrene, polyvinyl chloride and polybutylene are commonly used materials in agricultural plastic production. The most typical applications of plastics in intensive agriculture are plastic mulches, greenhouses and polytunnel covers, packaging and storage materials, and piping for irrigation purposes (Viljoen *et al*., 2023). As mentioned in Viljoen *et al.* (2023), one of the most common uses of plastics in intensive agriculture is as mulch film and their use has increased rapidly during the last decade (Divya and Sarkar, 2019; Mansoor *et al*., 2022), providing numerous benefits such as conserving soil moisture, regulating soil temperature and suppressing weed growth (Shah and Wu, 2019).

However, the plastic film mulches commonly used in agriculture, can degrade over time due to several factors including weather, exposure to UV radiation and mechanical stress. This degradation process breaks down the larger plastic (macro-plastics) into smaller fragments known as microplastics by changing their physical properties, color and surface characteristics (Ivleva *et al*.,2017; Zhang *et al*., 2021). The lack of recovery of plastic film mulches from the soil, as well as disposal of plastic materials is contributing to their accumulation in the environment.

Initially, the majority of study on microplastics was centered on the maritime environment, where a large number of studies examined the prevalence and abundance of microplastic particles in the ocean and along beaches, as well as the detrimental impacts of microplastics on marine life (Moller *et al*., 2020). Later scientists became interested in understanding their fate in freshwater lake and river systems, which are also significantly impacted by microplastic contamination and are important routes for the movement of microplastics (Moller *et al*., 2020). Not only the water ecosystem, but also soil can be contaminated with microplastics due to the fragmentation of discarded plastic materials or by leaching of buried waste existing in the landfills (Monkul and Ozhan, 2021) and the vertical movement of microplastic through soil (Rillig *et al*., 2017). Therefore, soil can be considered as the largest sink of microplastic (Li and Liu, 2022).

In addition to microplastics, plastic additives which are added in the plastic manufacturing process to enhance the properties of plastic products also badly impact on environmental health. When plastics break down, these additives can leach into ecosystems, causing toxicity in soil, water, and living organisms (Cao *et al*., 2023).

Therefore, this review aims to identify the uses and impacts of agricultural plastic mulches, and consequences of microplastics and plastic additives on soil and plants health in agriculture systems.

Uses of Plastic Film Mulches in Agriculture

Mulching is a widely accepted agricultural practice used to cover soil surface with various materials to enhance soil quality (Haapala *et al*., 2014). The mulching with organic agriculture was widely used in ancient agriculture and there is a history of using lithic mulching materials such as stone, gravel, pebble mulches (Haapala *et al*., 2014). The organic mulching materials are comprised of animal materials, straws of various cropping materials, grass clippings, dried leaves, saw dust and *etc* (Prem *et al*., 2020). Moreover, paper mulches were also used in ancient agriculture with different compositions and the quality of the raw materials used in the production method determines the longevity and functionality of paper mulches in agricultural systems. While, the synthetic mulches such as polythene and plastic films are also available in the market for use in crop fields.

Synthetic polythene films were initially used as a mulch for agricultural crops in the late 1950's in the USA, particularly for high-value crops (Emmert, 1957; Lalitha *et al*., 2010, Schales and Sheldrake 1965; Waggoner *et al*., 1960). According to Espi *et al*. (2006), the use of plastic mulch films in agriculture began in 1948 and expanded in the early 1950s. Additionally, low density polyethylene (LDPE) was introduced as a substitute for paper in vegetable mulching in early 1950s, marking the beginning of widespread usage of polymers in agriculture.

Although there are several uses of organic mulches on crop production, the use of plastic film mulches in agriculture has expanded considerably during the last decade around the world (Divya and Sarkar, 2019). Currently, it is considered as a common practice of vegetable farmers (Lalitha *et al*., 2010). Based on Shah and Wu. (2019), the Polyethylene, Polypropylene, Ethylene-vinyl acetate copolymer, and Poly-vinyl chloride are a few of the plastics being utilized in agriculture. The application of plastic film mulch in agriculture varies widely based on factors such as geographical region, crop type, and farming practices.

Plastic film mulches have been used in agriculture for several decades, offering various benefits such as increasing soil temperature and moisture, controlling weed growth and weed seed germination and nutrient conservation (Divya and Sarkar, 2019, Prem *et al* 2020). Based on some literature, plastic mulches are impervious to water as well as reduce water evaporation while increasing soil moisture holding capacity (Prem *et al*., 2020). And also, help in reducing soil nutrient leaching (Prem *et al*., 2020). On the other hand, there is a minimum disturbance to the soil and this reduces soil disturbance associated with plastic mulches contributes to long-term soil health and sustainability. Because the traditional tillage methods can lead to breakdown of soil aggregates and disruption of beneficial microbial communities. So, plastic mulches are involved in controlling soil erosion (Prem *et al*., 2020) as it acts as a protective barrier to protect the fertile top-soil layer.

Further, plastic mulches are used to double the agricultural income (Srinidhi and Nazereth, 2018) by boosting crop yield (Divya and Sarkar, 2019). For example, Hu *et al*. (2012), has identified that wheat plant yield and the straw biomass was significantly higher in plots mulched with plastic film compared to non-mulched plots. Additionally, the grain yield and P mass of above ground wheat crops were also significantly higher in plastic film mulched plots.

However, as highlighted by Liu *et al*. (2014), the long-term use of plastic mulching in soil can lead to notable consequences. For instance, it can increase the salt content of the topsoil. A study conducted over a period of 5 to 20 successive years, showed a potential rise in salt content of 122 to 146 %. This limited leaching due to plastic mulches may cause a slow buildup of salts over time in regions where they naturally occur in the soil. The accumulated salts can lead to soil salinity which can negatively impact crop yield and productivity. Therefore, careful monitoring is crucial when using plastic mulches in the long run to maintain soil productivity.

Moreover, the improper disposal of plastic mulches can act as a source of pollution. As mentioned in Briassoulis *et al*. (2013), burning of agricultural plastics can releases environmental pollutants such as dioxins, furans. Hence, Mitrano (2019) has reported that the microplastic and nanoplastic coming from plastic degradation has a huge impact on various ecosystems. This will lead to accumulation of persistent organic pollutants (Wei and Zimmermann, 2017). In the meantime, releasing these tiny particles into the farming systems poses a major threat to beneficial soil organisms and could potentially enter the food chain (Astner *et al*., 2019).

Impact of Plastic Film Mulches on Soil

Agricultural plastic mulches can have both positive and negative impacts on soil health. The plastic mulches can result in complex changes in the soil environment through modifying various physicochemical properties. For instance, plastic mulches are applied with the aim of changing soil temperature and moisture levels, control weeds and pests, reducing evaporation, minimizing soil erosion and compaction (Lalitha *et al*., 2010, Shah and Wu, 2020).

As indicated in Lalitha *et al*. (2010), several types of plastic mulches can serve as a barrier to retain methyl bromide, an effective fumigant and ozone depleter, in the soil. Further, Hu *et al*. (2012), reported that soil water availability is better under plastic mulch compared to non-mulched soils. The use of plastic mulches along with drip irrigation can improve water use efficiency (Lalitha *et al*. (2010). This is because plastic mulches alter the microclimate around the plant by changing the surface radiation budget and conserving soil moisture (Liakatas *et al*., 1986).

However, though these products have helped to increase agricultural production, there is a high risk of releasing microplastics and their additives to the soil ecosystem during the degradation process in the long term. Hence, the soil may be a significant long-term sink for additives and microplastic particles.

What is Microplastic?

Microplastics are plastic particles which have been identified as a growing pollutant that are widely distributed in the environment (Ferreira *et al.* 2018; de Souza Machado *et al.* 2020). Simply based on literature the presence of these tiny plastic particles, commonly referred to as "microplastics"(Anderson *et al.*, 2016; Browne *et al.*, 2011). Frias and Nash (2019), proposed that the microplastics are "any synthetic solid particle or polymeric matrix, with regular or irregular shape and with size ranging from 1 μm to 5 mm, of either primary or secondary manufacturing origin, which are insoluble in water". According to ISO/TR 21960:2020, microplastics have been categorized into two fractions, large (1-5 mm) and small fractions (0-1 mm).

Microplastic Impact on Environment Pollution

The substantial amount of plastic waste is incinerated or released to landfills or discharged to the environment, resulting in significant environmental and health consequences (Wang *et al.*, 2020(a)). It is estimated that < 10 % of used plastic is recycled in the USA (Cessi *et al.*, 2014; Osman *et al.*, 2023). Moreover, significant plastic residues still remain in fields even after plastic film mulches have been retrieved from the soil at the end of the growing season (Ding *et al.*, 2021).

As indicated in the Zhang et al. (2021), microplastics found in the environment are diverse in terms of their complexity of forms, shapes, sizes, and composition, although polyethylene and polypropylene microplastics are prevalent (Klein *et al.*, 2015). Eco-toxicity depends on the polymer composition and additive content (Zhang *et al.*, 2021). Once microplastic are formed from plastics they can exist in the environment for a long period of time and have a potential to enter marine life due to ingestion. Moreover, there is a potential to disrupt the food chain and harm to species at all levels. Ultimately it can make a huge threat to the ecosystem and human health. As an example, Monkul and Ozhan (2021) has mentioned that the pollution from microplastics poses a threat to marine and freshwater ecosystems, agricultural production, groundwater, plant growth, and even human and animal health.

For instance, chlorinated plastic has the potential to leak dangerous chemicals into the soil around it (Gondal *et al.*, 2023). These chemicals can then seep into nearby water sources, including groundwater, and the ecosystem. Moreover, studies on microplastics have revealed that synthetic polymer particles can be found in all environments including Arctic Sea ice, waters of remote mountain lakes and even agricultural soils.

Further, the plastic additives can limit the uptake of water and nutrients through roots, and can accumulate in the root, shoot, and leaves (Khalid *et al.*, 2020). Ultimately, this can result in reduced crop productivity and pose a threat to global food security. Hence, agricultural soils need to be protected from further degradation and contamination as preserving soil health is crucial for ensuring sustainable agriculture and safeguard food production for future generations.

Microplastic Impact on Soil and Plant Health

The presence of microplastics in soil ecosystems can have complex and numerous implications and it is important to identify the overall impact of microplastics on soil health and function. Based on Maddela *et al.* (2023), the soil pollution by microplastics is more severe than in the aquatic environment especially where agricultural soils are exposed to high concentrations of microplastic pollution.

Based on the literature, 50-80 % of microplastic exists in soils are less than 1 mm in size (Li and Liu, 2021). Moreover, some have reported that the content of soil microplastic is around 1 % of the soil mass (Huang *et al.*, 2019; Li and Liu, 2021).

Soil microplastics have been shown to negatively impact on soil organisms. For instance, Kim *et al.* (2020) has observed that the microplastics and microplastic additives can be a toxic component for soil nematodes. In addition, microplastics can inhibit the growth of collembolans (Zhu *et al.*, 2018) and the activity of soil microbial communities (Zang *et al.*, 2020).

On the other hand, microplastic particles in size ranging from less than 5 mm in size can alter soil physicochemical properties. Their presence may influence soil structure, water retention, porosity as well as the soil aeration. Some studies have reported that microplastics tend to disrupt soil structure. For instance, Liang *et al.* (2019), has mentioned that microplastic can destroy the soil aggregation structure by lowering the macro-aggregate contents. Similarly, Rilling *et al*. (2021), reported that the most notable impact of microplastic is the disturbance to the soil structure, since it affects soil aggregate stability and bulk density of the soil. According to Zhou *et al.* (2023), the addition of polyester and polypropylene microplastics has decreased the bulk density in crops such as *Zea maize*, *Glycine max* and *Arachis hypogaea*.

Nevertheless, the changes in soil structure can impact the spatial distribution of mycorrhizal networks and alter the nutrient availability for plants. Therefore, microplastics are thought to affect the cycling of nutrients in the soil.

In addition to that, microplastics can create various physiological toxicities to plants. For instance, plant biomass reduction, intracellular oxidative stress burst, inhibition of photosynthesis process, retardation of water and nutrient absorption, seed germination (Zhou *et al*., 2023). However, the impact of different types of microplastic under different plants are limited (Zhou *et al.*, 2023).

As indicated in Qi *et al*. (2018), the low-density polyethylene (LDPE) and biodegradable (BD) microplastics have a negative impact on plant growth and reproduction of *Triticum asetivum*. Moreover, plant culm diameter, plant height, leaf area, root shoot ratio, has unfavorable impacts with LDPE microplastics (Li *et al*., 2021).

Wu *et al*. (2020) observed that polystyrene microplastics have decreased the shoot biomass and rice yield of *Oryza sativa* (Rice). Meng *et al*. (2021) has reported that the exposure of 0.5 % LDPE microplastics lead to reduced leaf chlorophyll content in *Phaseolus vulgaris* (Common bean), while the addition of 1 % of LDPE microplastics has significantly increased the leaf area of *P. vulgaris*. The Boots *et al.* (2019) has reported that the biodegradable polylactic acid microplastics, causes for decrease the seed germination and shoot height in *Lolium perenne* (Perennial ryegrass).

Therefore, results show that microplastics can alter crop production and growth of different crop types in a range of agricultural systems. However, most studies have been limited to greenhouse and laboratory conditions. Hence, it is essential to investigate the impact of microplastics under real field conditions with different crops to ensure food safety and security in the long term.

Conclusion:

The extensive use of plastic film mulches has contributed significantly to improving crop productivity by enhancing soil moisture retention, regulating temperature, and suppressing weed growth. However, their long-term environmental implications cannot be ignored. The degradation of plastic mulches results in the formation of microplastics, which persist in the soil and pose serious risks to soil health, plant growth, and broader ecological systems.

To mitigate these impacts, there is an urgent need for sustainable alternatives to conventional plastic mulches, such as biodegradable materials, improved waste management strategies, and policies promoting responsible plastic use in agriculture. Addressing the challenges posed by microplastics is crucial for ensuring food security, and safeguarding environmental health.

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Guest Articles

Salt Stress: An Invisible Threat to Global Food Production

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Introduction

Imagine living in a world where once fertile farmlands turn dry and lifeless, and the crops we rely on struggle to grow. This is not something that will happen far in future, it is happening right now due to increasing soil salinity. Salt stress is a growing crisis that's making it harder for farmers to grow food, pushing both them and consumers into a tough spot. Despite its seriousness, this issue is still overlooked, even as fertile lands slowly turn into salty wastelands. If we don't take action, salt stress will continue to threaten agriculture and put countless livelihoods at risk.

The consequences of ignoring salt stress are severe, potentially leading to widespread food shortages, economic instability, and rising social unrest. Climate change and unsustainable agricultural practices will only make the situation worse. Addressing salt stress is no longer just an agricultural issue; it is a critical global challenge that requires urgent attention to ensure food security for a growing population.

How Does This Salty Stress Occur

Salt stress occurs when excessive salts accumulate in the soil, hindering plant growth. According to Munns and Tester (2008) and Zörb *et al.* (2019), sodium ions (Na^+) are the primary contributors to soil salinity, while Cl^-, Mg^{2+}, SO_4^{2-}, and HCO^{-3} play a minor role.

Salt stress arises from various sources. Natural processes like weathering of rocks can release salts into the environment over time. Unfortunately, our own actions are making the problem even worse. In dry regions, poor irrigation causes water to evaporate too quickly, leaving excess salt behind in the soil. Climate change is also playing a role, as rising sea levels push salty water into coastal farmlands, turning once-fertile fields into lifeless wastelands. On top of that, the excessive use of certain fertilizers adds to the problem, making it even harder for farmers to grow healthy crops and sustain their livelihood.

How Salt Stress Affects Crops & Food Production

High salt levels prevent crops from absorbing water properly, causing dehydration, nutrient imbalances, reduced photosynthesis and ultimately reduced the yield. Staple crops like rice, wheat, and maize, which feed billions, are especially at risk.

Salinity not only lowers crop yields but also impacts the quality of the produce, making it less marketable and harder to consume. Excessive salt alters the nutrient composition of crops, resulting the reduction of their nutritional value. Also can cause physiological disorders in fruits and vegetables which affect their taste, texture, and marketability.

As a result of salt buildup, soil fertility is drained, eventually turning once-productive farmland into barren land. This will be the foremost reason for the reduction of the amount of land available for food production. This issue is particularly severe in arid and semi-arid regions, further limiting the land available for cultivation.

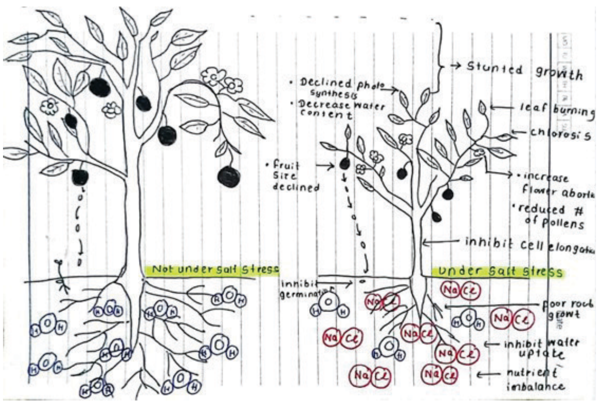

Figure 1: Schematic representation of plant response to salt stress

When salt washes away from affected areas, it can contaminate rivers and lakes like freshwater sources, putting fish and other aquatic life at risk. This not only harms the environment but also affects fishing and aquaculture, making it harder to produce food. The utilization of saline water for both the cultivation of forage crops and as a drinking source for livestock can harm their health and ultimately affect meat and dairy production.

The Global Impact on Food Production

The United Nations Food and Agriculture Organization (FAO) predicts that global food production will increase significantly over the next 50 years due to the ongoing growth in the human population, expected to rise by 2.3 billion. To meet this demand, agriculture will need to produce 70% more food. Addressing soil salinity is essential to safeguarding future food security and ensuring a stable food supply for generations to come.

Between 1986 and 2016, the land area affected by soil salinity increased from 915 million hectares to 1,069 million hectares. This trend highlights the growing problem of land degradation due to salt, with more and more soil becoming unfit for farming each year. Countries like India, China, Pakistan, Australia, and parts of the Middle East face severe challenges due to salt-affected lands. Coastal areas, where contaminate with seawater are especially at a risk. If left unaddressed, salt stress could significantly reduce food availability and increase prices, putting pressure on both farmers and consumers.

Innovative Solutions and Future Prospects

Since salt stress is a serious challenge, it is not impossible to overcome. A combination of technological, biological, and management solutions is essential to reduce its impact and secure food supplies for the future:

- **Salt-Tolerant Crops:** Developing and cultivating crop varieties that can withstand salt stress is vital. Ongoing research in this field is showing promising results, offering hope for more resilient crops in the future.
- **Improved Irrigation Techniques:** Precision irrigation and rainwater harvesting can help

minimize salt buildup. By adopting to efficient irrigation techniques, like drip irrigation, can significantly reduce water waste and help prevent salt accumulation in the soil. This method delivers water directly to the plant roots, aiding in minimizing evaporation and runoff while ensuring optimal moisture levels for crops.

- **Soil Management Strategies:** Using organic matter, cover crops, phytoremediation and crop rotation can significantly improve soil health and help reduce salinity. Establishing effective drainage systems is essential to maintain soil health and minimize the accumulation of salt over time. Moreover, application of biostimulants is making another avenue of upbringing the salt stress tolerance in plants.
- **Microbial Solutions:** Beneficial bacteria (plant growth-promoting rhizobacteria (PGPR) and cyanobacteria), mycorrhizal fungi can enhance plant resilience to salt stress.
- **Advanced Technologies:** Working hand in hand with nanotechnology, mutation breeding, marker assisted breeding, genetic engineering, CRISPR/CAS system like novel technologies offer promising results.
- **Policy and awareness:** Government must implement policies that encourage sustainable land management practices. Raising the awareness of the public and stakeholders about its impact will help to obtain long-term solutions.

The Way Forward

Protecting and restoring soil health is not solely the responsibility of farmers. It requires a concerted effort from governments, researchers, consumers and the entire food industry. Investing in sustainable farming practices and innovative agricultural technologies is essential to overcoming this challenge. Governments can play a key role by offering incentives, subsidies, and regulations that promote sustainable farming practices. Researchers can contribute by developing innovative technologies and strategies to improve soil quality. Meanwhile, consumers can also make a difference by choosing to buy from farmers who are dedicated to sustainable agriculture. It is a shared responsibility to ensure healthy soil and a secure food future. With such proactive measures, we can protect our farmlands and ensure a future where food remains plentiful and accessible for all.

Salt stress is an urgent yet frequently underestimated challenge to global food security. By understanding its impact and implementing effective solutions, we can safeguard agriculture for generations to come. The moment to act is now—before more fertile lands turn to barren, salt-ridden wastelands.

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Next-Generation Emerging Perovskite Solar Cells: Shaping the Future for Clean and Sustainable Energy

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Perovskite solar cells (PSCs) have emerged as a revolutionary technology in the renewable energy sector, offering a unique combination of high efficiency, low production costs, and versatile applications. Over the past decade, the efficiency of PSCs has emerged from an initial 3.8% to an impressive 27.3%, surpassing traditional silicon-based solar cells in certain configurations (Basumatary & Agarwal, 2022). This rapid progress is attributed to the exceptional optoelectronic properties of perovskite materials, such as their high absorption coefficients, tunable bandgaps, and excellent charge carrier mobility (Jošt et al., 2020). These properties enable PSCs to achieve high power conversion efficiencies (PCE) while maintaining low material and manufacturing costs.

One of the most compelling advantages of PSCs is their compatibility with flexible and lightweight designs, making them suitable for a wide range of applications, including building-integrated photovoltaics (BIPV), portable electronics, and even wearable devices (Mishra *et al.*, 2021). Additionally, PSCs can be fabricated using low-temperature, solution-based processes, which significantly reduce energy consumption and production costs compared to the high-temperature processes required for silicon solar cells (Ibn-Mohammed et al., 2017). Despite these advantages, challenges remain, particularly in improving the long-term stability and durability of PSCs under real-world conditions. Issues such as sensitivity to moisture, heat, and UV radiation have hindered their commercialization (Arora *et al.*, 2019). However, ongoing research is focused on developing advanced encapsulation techniques, stable perovskite compositions, and innovative device architectures to address these challenges. With continued advancements, PSCs have the potential to revolutionize the solar energy industry, making clean and sustainable energy more accessible and affordable worldwide.

The Sun's Potential: Unlocking a Greener Tomorrow

The global energy landscape is undergoing a profound transformation as the world tackles with the dual challenges of rising energy demand and the depletion of finite fossil fuel resources. According to the International Energy Agency (IEA), global energy consumption is projected to increase by nearly 50% by 2050, driven by population growth, urbanization, and industrialization (Bilgili *et al.*, 2015). This escalating demand, coupled with the environmental impact of fossil fuel combustion, has underscored the urgent need for renewable energy solutions.

Solar energy, in particular, has emerged as a cornerstone of the global transition to sustainable energy. The sun provides an abundant and virtually infinite energy source, capable of meeting the world's energy needs many times over (Ray, 2019). Solar photovoltaic (PV) technology, which converts sunlight directly into electricity, has seen remarkable advancements in recent years, with significant reductions in costs and improvements in efficiency. The levelized cost of electricity (LCOE) from solar PV has dropped by over 80% since 2010, making it one of the most cost-competitive energy sources available today (Liu *et al.*, 2023).

In addition to its economic viability, solar energy offers significant environmental benefits. Unlike fossil fuels, solar power generation produces no greenhouse gas emissions, helping to mitigate climate change and reduce air pollution (Bilgili *et al.*, 2015). Furthermore, solar energy systems can be deployed at various scales, from small rooftop installations to large utilityscale solar farms, making them adaptable to diverse geographic and economic contexts. As the world strives to achieve net-zero carbon emissions by mid-century, solar energy will play a pivotal role in decarbonizing the energy sector and ensuring a sustainable future.

Thin-Film Solar Cells: Challenges and Potential

Thin-film solar cells represent a promising alternative to traditional silicon-based solar cells, offering several advantages, including reduced material usage, lower weight, and flexibility. These cells are fabricated by depositing one or more thin layers of photovoltaic material onto a substrate, such as glass, plastic, or metal. The thickness of these layers is typically in the range of a few micrometers, significantly thinner than the hundreds of micrometers required for silicon solar cells (Sun *et al.*, 2022). This reduction in material usage not only lowers production costs but also enables the development of lightweight and flexible solar panels, which can be integrated into a variety of applications, including curved surfaces and portable devices.

Despite their potential, thin-film solar cells face several challenges that have limited their widespread adoption. One of the primary issues is the relatively lower efficiency of thin-film technologies compared to silicon solar cells. For example, cadmium telluride (CdTe) and copper indium gallium selenide (CIGS) thin-film solar cells have achieved efficiencies of around 22% and 23%, respectively, which, while impressive, still lag behind the efficiencies of silicon solar cells (Buonomenna, 2023). Additionally, the use of toxic materials such as cadmium and the complexity of manufacturing processes have raised environmental and economic concerns (Maalouf *et al.*, 2023).

Recent advancements in perovskite materials have opened new possibilities for thin-film solar cells. Perovskites offer the potential to achieve high efficiencies at low costs, with the added benefit of being compatible with flexible substrates (Liu et al., 2019). Researchers are exploring hybrid thin-film solar cells that combine perovskites with other materials, such as silicon or CIGS, to create tandem solar cells with enhanced efficiency and stability. These innovations could address the limitations of traditional thin-film technologies and pave the way for their large-scale deployment.

The basic structure of a perovskite solar cell typically consists of five key layers:

1. **Transparent Conductive Oxide (TCO) Layer:** This layer serves as the front electrode, allowing light to enter the cell while conducting electricity.
2. **Electron Transport Layer (ETL):** The ETL facilitates the movement of electrons generated by light absorption to the external circuit.
3. **Perovskite Absorber Layer:** This is the core of the solar cell, where light absorption and charge generation occur. The perovskite material, typically a hybrid organic-inorganic compound, exhibits excellent light-harvesting properties (Jošt *et al.*, 2020).
4. **Hole Transport Layer (HTL):** The HTL transports positively charged holes to the back electrode, completing the electrical circuit.
5. **Metal Electrode:** This layer acts as the back electrode, collecting the charges and enabling the flow of electricity.

This layered architecture enables efficient light absorption, charge separation, and electron transport, contributing to the high-power conversion efficiency of PSCs. Figure 1 below depicts a basic schematic view of the layer structure of perovskite solar cells.

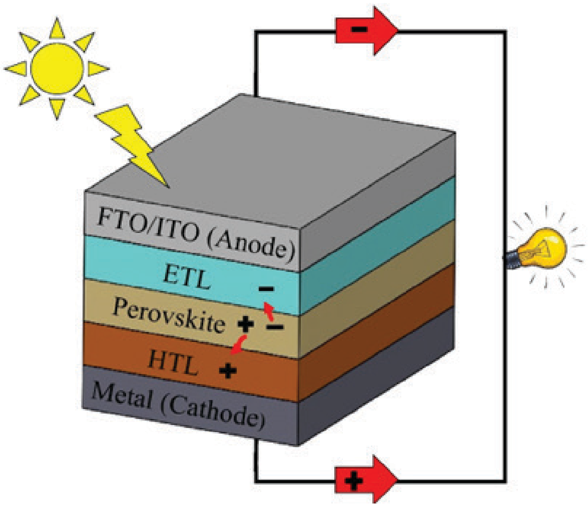

Figure 1: Basic structure of perovskite solar cell

Boosting PSCs: Stability for Commercial Viability

The commercialization of perovskite solar cells hinges on addressing their key challenges, particularly their long-term stability and durability. While PSCs have demonstrated remarkable efficiencies, their operational lifespan remains a critical barrier to widespread adoption. Perovskite materials are inherently sensitive to environmental factors such as moisture, oxygen, heat, and UV radiation, which can lead to degradation and performance loss over time (Arora *et al*., 2019).

To overcome these challenges, researchers are pursuing several strategies:

1. **Material Engineering:** Developing more stable perovskite compositions by incorporating additives or substituting elements to enhance their resistance to environmental factors (Basumatary & Agarwal, 2022).
2. **Protective Layers:** Introducing advanced encapsulation materials and techniques to shield the perovskite layer from moisture and oxygen (Ibn-Mohammed *et al.*, 2017).
3. **Device Architecture Optimization:** Designing innovative device structures, such as tandem solar cells, to improve efficiency and stability (Jošt *et al*., 2020).
4. **Scalable Manufacturing:** Exploring cost-effective and scalable fabrication methods, such as roll-to-roll processing and inkjet printing, to enable large-scale production (Mishra *et al*., 2021).

One of the most promising approaches is the development of tandem solar cells, which combine perovskite materials with silicon or other semiconductors to achieve higher efficiencies. Tandem solar cells use absorption properties of different materials, enabling them to capture a broader spectrum of sunlight and convert it into electricity more efficiently. For example, perovskite-silicon tandem solar cells have achieved efficiencies exceeding 30%, surpassing the theoretical limits of single-junction solar cells (Kim *et al*., 2020).

As research and development efforts continue to address stability and scalability challenges, PSCs are getting closer to commercial viability. With their potential to deliver high efficiencies at low costs, PSCs could play a transformative role in the global transition to clean and sustainable energy, helping to mitigate climate change and meet the world's growing energy needs.

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